13 July 2005

MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Five
QUANTITY SUMMARIES

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Chapter Five
QUANTITY SUMMARIES

In addition to preparing clear and concise construction plans, as described in Chapter Four, the designer needs to compile an accurate estimate of the project construction quantities. This information leads directly to the Engineer's Estimate, which combines the computed quantities of work and the estimated unit bid prices. An accurate estimate of quantities is critical to prospective contractors interested in submitting a bid on the project. Chapter Five presents detailed information on estimating quantities for highway construction projects.

5.1 GENERAL

5.1.1 Guidelines for Preparing Quantity Summaries

When preparing quantity summaries, the designer should consider the following guidelines:

1. Specifications. Cross check all items against the *Standard Specifications* and the *Supplemental Specifications* to ensure that the appropriate pay items, methods of measurement and basis of payment are used.

2. Computations. For the preliminary summaries, prepare a separate computation sheet for each item used on the project. Include all computation sheets in the project work file.

3. Rounding. The quantity of any item provided in the summaries should match exactly with the figure provided on the computation sheets. Note any required rounding of raw estimates on the computation sheets. Unless stated otherwise, do not round the calculations until the value is incorporated into the summary frames.

4. Significant Digits. Perform quantity calculations with careful regard to the implied correspondence between the accuracy of the data and the given number of digits. In all calculations, the number of significant digits retained should be such that accuracy is neither sacrificed nor exaggerated. Use the following rules to determine the appropriate number of significant digits:

   a. Number of Digits. Any digit that is necessary to define the specific value or quantity is considered significant. When measured to the nearest 1 ft (m), a distance may be recorded as 157 ft (m); this number has three significant digits. If the measurement had been made to the nearest 0.1 ft (0.1 m), the distance may have been 157 ft (m); this number has four significant digits.

Zero may be used to indicate either a specific value, like any other digit, or a number's order of magnitude. The area of PCCP (Portland Cement Concrete Pavement) shown on a set of plans, rounded to thousands, was 120 000 ft^2($m^{2)}$. The three left-hand digits of this number are significant; each measures a value. The three right-hand digits are zeros which merely indicate the order of magnitude of the number rounded to the nearest thousand. The identification of significant digits is only possible through knowledge of the circumstances. For example, the number 1000 may be rounded from 965, in which case only one zero is significant, or it may be rounded from 999.7, in which case all three zeros are significant.

b. Addition and Subtraction. When adding and subtracting quantities, do not express the answer's significant digits any further to the right than occurs in the least precise number. The following illustrates this rule:

Consider the addition of three numbers drawn from three sources, the first of which reported data in millions, the second in thousands, and the third in units:

$$\begin{array}{r} 163\ 000\ 000 \\ 217\ 885\ 000 \\ +\ \ 95\ 432\ 768 \\ \hline 476\ 317\ 768 \end{array}$$

The total should be rounded to 476 000 000.

c. Multiplication and Division. Do not express the product or quotient of multiplication and division calculations with any more significant digits than are used in the calculations. The following illustrates this rule:

Multiplication:

113.2 x 1.43 = 161.876, round to 161.9

Division:

113.2 ÷ 1.43 = 79.16, round to 79.2

5. Quantity Splits. Some projects will require quantity splits for work conducted under various financing arrangements. The quantities for district-wide pavement marking projects do not need to be split. Determine the need to separate project quantities into funding categories during the Preliminary Field Review. For projects requiring quantity splits, organize the summary frames to readily identify each division subtotal and the total of all divisions. Show a subtotal in the summary frames for the following:

   a. each county,
   b. each funding source, and
   c. inside and outside reservation boundaries.

Show all splits if more than one split applies to a project.

6. Preliminary Cost Estimate. Use only the total values from the summary frames to develop the Preliminary Cost Estimate. All items described in the plans that are to be included in the cost estimate must be shown in the summaries. Chapter Seven provides the Department criteria for preparing construction cost estimates. The Preliminary Cost Estimate is utilized by the Board of Review and the Contract Plans Section in their preparation of the final Engineer's Estimate.

5.1.2 Computer Estimates

For most projects, use the computer to develop the quantity estimates for earthwork and other similar items. All other elements are typically calculated manually. For small projects, it may be more efficient to manually calculate all quantities, including earthwork.

The designer should review the instruction manuals for GEOPAK to determine how to properly use the software for estimating purposes. GEOPAK can generate most, but not all, project quantities. Give special consideration to how the design is prepared on the computer (e.g., cell names, levels, processing procedures) to allow the software to determine the quantities. Contact the MDT CADD Coordinator or the section lead CADD operator for additional assistance with GEOPAK.

5.1.3 Units of Measurement

Report quantity estimates in summary frames for all contract bid items consistent with the terms and units of measurement presented in the *Standard Specifications*. Figure 5.1A illustrates typical rounding criteria that should be used for each frame on the Summary Sheets. Note that certain elements (e.g., pipe lengths, guardrail) are rounded based on standard manufacturer sizes. Unless stated elsewhere in this Chapter, round quantities consistent with the criteria presented in Figure 5.1A.

5.1.4 Item Codes

Each item used for measurement and payment in construction is identified by a 9-digit number with a title and description. These numbers are used by the Department's Construction Management System for tracking the project through construction. Note that the first three digits of the item number are coordinated with the *Standard Specifications*. For example, Item #606010030 “Guard Rail-Steel” is referenced to Section 606 “Guardrail, Median Barrier Rail and Guide Post” of the *Standard Specifications*.

The Contract Plans Section is responsible for numbering and naming the various items used in construction. Contact the Contract Plans Section or the Contractors System link on the MDT web site to obtain a copy of the official item list. Only use the official name and description in contract plans. Submit all proposed changes or additions to this list to the Contract Plans Section.

Item	Measured Unit	Rounding Criteria
GRADING FRAME		
Unclassified Excavation Embankment + Embankment in Place Borrow Roadway Compaction	cubic yard, cy cubic meter, m^3	1
ADDITIONAL GRADING FRAME		
Excavation Embankment + Embankment in Place Additional Excavation Additional Embankment in Place	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
SUBEXCAVATION FRAME		
Subexcavation Special Borrow	cubic yard, cy cubic meter, m^3	1
DIGOUTS FRAME		
Digout Excavation Special Borrow	cubic yard, cy cubic meter, m^3	1
MUCK EXCAVATION FRAME		
Muck Excavation Special Borrow	cubic yard, cy cubic meter, m^3	1
CLEARING and GRUBBING FRAME		
Clearing and Grubbing	Acre (hectare, ha)	0.1
REMOVE STRUCTURES FRAME		
Structures	Lump Sum	1
OBLITERATE ROADWAY FRAME		
Stations	number of 100 ft (m) stations	1
EQUIPMENT and ROAD LEVELER OPERATIONS FRAME		
Dozer Motor Grader Road Leveler	Hour, hr	1
DETOUR FRAME		
Construct, Maintain and Remove	Lump Sum	1

SUMMARY FRAMES ROUNDING CRITERIA

Figure 5.1A

Item	Measured Unit	Rounding Criteria
CULVERT FRAME (Option, No Option and Approach)		
Length of Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
Relay Pipe	foot, ft (meter, m)	2 (0.5)
Culvert Excavation	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Foundation Material Bedding Material	cubic yard, cy cubic meter, m^3	1
Class “DD” Concrete Culvert Riprap	cubic yard, cy cubic meter, m^3	0.1
Height of Cover Remove Culvert	Foot, ft (meter, m)	0.1
Geotextile	square yard, sy (meter, $m^{2)}$	1
CULVERT SUMMARY RECAP FRAME		
Length of Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
Relay Pipe	feet,ft (meters, m)	2 (0.5)
Clean Culvert	Foot, ft (meter, m)	1
Remove Culvert	Foot, ft (meter, m)	0.1
Culvert Excavation	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Foundation Material Bedding Material	cubic yard, cy cubic meter, m^3	1
Class “DD” Concrete Culvert Riprap	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Geotextile	square yard, sy (square meter, $m^{2)}$	1
STOCK PASS FRAME		
Length of Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
Plant Mix Surfacing	Ton (Metric ton, MT)	1
Crushed Top Surfacing Foundation Material Bedding Material	cubic yard, cy cubic meter, m^3	1

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
Asphalt Cement	Ton (metric ton, t)	0.1
Culvert Excavation	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Class “DD” Concrete Culvert Riprap	cubic yard, cy cubic meter, m^3	0.1
Geotextile	square yard, sy square meter, m^2	1
Height of Cover	foot, ft (meter, m)	0.1
UNDERDRAIN FRAME		
Culvert Excavation	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Filter Material	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Geotextile	square yard, sy (square meter, $m^{2)}$	1
Plastic Pipe	2 foot increment, ft 0.5 meter increment, m	2 0.5
STORM DRAINS and DRAINAGE STRUCTURES FRAME		
Pipe Lengths Slotted Drain	0.1 foot increment, ft 0.1 meter increment, m	0.1 0.1
Manholes Tee Sections Drop Inlets Curb Inlets Irrigation Turnouts Adjustments	each, ea	1
Bedding Material	cubic yard, cy (cubic meter, $m^{3)}$	1
Class “DD” Concrete	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Trench Excavation Culvert Excavation	5 cubic yard increment, cy 5 cubic meter increment, m^3	5
Height of Cover	Foot, ft (Meter, m)	0.1
WATER VALVE BOXES FRAME		
Water Valve Box - Adjust to Grade	each, ea	1

* Where existing stationing is utilized, the dimensions may only be available to the nearest 0.1 meters.

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
EMBANKMENT PROTECTORS FRAME		
Embankment Protector – 12” (300 mm)	2 foot increment, ft 0.5 meter increment, m	2 0.5
Bituminous Curbing	foot, ft (meter, m)	0.1
Bank Protection	cubic yard, cy (cubic meter, $m^{3)}$	0.1
MANHOLE FRAMES		
Manhole - Adjust to Grade	each, ea	1
SURFACING and ADDITIONAL SURFACING FRAMES		
Distance *	Foot, ft (meter, m)	0.01
Hydrated Lime Plant Mix Surfacing Blotter	ton (metric ton, MT)	1
Cover Material	square yard, sy square meter, m^2	1
Traffic Gravel	cubic yard, cy (cubic meter, $m^{3)}$	1
Asphalt Cement Prime Dust Palliative Seal Curing Seal Portland Cement Fly Ash	ton, (metric ton, MT)	0.1
Crushed Top Surfacing Crushed Base Course Crushed Aggregate Course	cubic yard, cy or ton cubic meter, m^3 or metric ton, t	1
Tack and Aggregate Tack	gallon, gal (liter, L)	1
Cement Treated Base (preferred)	cubic yard, cy (cubic meter, m)	1
Cement Treated Base Cement Treated Pulverized Base Portland Cement Concrete Pavement	square yard, sy square meter, m^2	1
COLD MILLING FRAME		
Cold Milling	square yard, sy square meter, m^2	1

* Where existing stationing is utilized, the dimensions may only be available to the nearest 0.1’ (0.1 m).

SUMMARY FRAMES ROUNDING CRITERIA

(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
FINISH GRADE CONTROL FRAME		
Course Mile (Kilometer)	mile, mi (kilometer, km)	0.1
BITUMINOUS PAVEMENT REMOVAL and IN-PLACE ASPHALT PAVEMENT RECYCLING FRAMES		
Bituminous Pavement Removal Recycle Asphalt Pavement (in-place)	square yard, sy square meter, m^2	1
Recycle Agent	gallon, gal (liter, L)	1
NEW SIDEWALKFRAME		
4” (100 mm) Concrete Sidewalk 6” (150 mm) Concrete Sidewalk	square yard, sy square meter, m^2	0.1
Width	foot, ft (meter, m)	0.1
NEW CONCRETE CURB and GUTTER FRAME		
Curb and Gutter Cut-off Curb Median Curb	foot, ft meter, m	0.1
NEW MAILBOX FRAME		
Mailbox	each, ea	1
TOPSOIL FRAME & SEEDING FRAME		
Salvaging and Placing	cubic yard, cy cubic meter, m^3	1
Seed Fertilizer Condition Seedbed Mulch Revegetation	acre hectare, ha	0.1
Revegetation	Lump sum (less than 1 acre or ha)	
RANDOM RIPRAP FRAME		
Riprap	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Geotextile	sq yard, sy (sq meter, $m^{2)}$	1
Revegetation	sq yard, sy (sq meter, $m^{2)}$	1
CONCRETE DRAINAGE CHUTES FRAME		
Class “AC-DC” Concrete Bank Protection	cubic yard, cy cubic meter, m^3	0.1

SUMMARY FRAMES ROUNDING CRITERIA
(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
GUARDRAIL FRAME		
New Metal Guardrail Intersecting Roadway Terminal Section	12.5’ increment, ft 3.81 meter increment, m	12.5 3.81
Box Beam Guardrail	18 foot increment, ft 5.49 meter increment, m	18 5.49
Remove Guardrail Cable Guardrail	Foot, ft meter, m	0.1 0.01
Bridge Approach Section	unit	1
Optional Terminal Section Optional Box Beam Terminal Section Box Beam Terminal Section Type 2 One-Way Departure Terminal Section Cable Guardrail Terminal Section	each, ea	1
MEDIAN CONCRETE CURB FRAME		
Concrete Sidewalk (4” or 100 mm)	square yard, sy square meter, m^2	0.1
Median Curb Remove and Reset	foot, ft meter, m	0.1
FENCING FRAME		
Fence Types Temporary Fence	foot, ft (0.1 meter, m)	1’ (0.1 m)
Panels Deadman	each, ea	1
Gates	2 foot increment, ft 0.6 meter increment, m	2 0.6
CATTLE GUARD FRAME		
New Reset Remove	each, ea	1
PAVEMENT MARKING FRAME		
Paint Words and Symbols, Epoxy	gallon, gal (liter, L)	1

SUMMARY FRAMES ROUNDING CRITERIA
(Continue)

Figure 5.1A

Item	Measured Unit	Rounding Criteria
Plastic Pavement Striping	foot, ft (meter, m)	1
Words and Symbols, Plastic	square foot, sq ft square meter, m^2	0.1
Temporary Pavement Markings Epoxy Pavement Marking	mile, mi (kilometer, km)	0.1
SURVEY MONUMENTS and BOXES FRAME		
Location	each, ea	1
CONCRETE MEDIAN RAIL FRAME		
Concrete Median Rail	Each(10' or 3.05 m increment)	1
Impact Attenuator	each, ea.	1
PLANT-MIX LINED DITCH FRAME		
Plant-Mix Lined Ditch	foot, ft (meter, m)	0.1
RUMBLE STRIPS FRAME		
Rumble Strip	mile, mi (kilometer, km)	0.1
IRRIGATION STRUCTURES FRAME		
Class "DD" Concrete Riprap	cubic yard, cy (cubic meter, $m^{3)}$	0.1
Concrete Ditch Liner	Foot, ft (meter, m)	0.1
Geotextile	square yard, sy square meter, m^2	1
Headgate Canal Gate Remove Irrigation Structure Check/Turnout	each, ea	1

SUMMARY FRAMES ROUNDING CRITERIA
(Continue)

Figure 5.1A

5.2 EARTHWORK COMPUTATIONS

5.2.1 Computer Computations

As stated in Section 5.1.2, most highway mainline earthwork computations are determined using the computer. Earthwork quantities for small projects, approaches, side roads, ditches and additional grading features may need to be calculated manually (see Section 5.2.2). For the computer to calculate the mainline earthwork quantities, the following information is required:

1. horizontal and vertical roadway alignments;
2. typical sections;
3. terrain data;
4. shrink and swell factors;
5. cut and fill slope rates; and
6. identification of sections not to be included (e.g., bridge sections).

The computer will provide a listing of the quantities for each station. Present these amounts on the cross sections as described in Section 4.3.11. The quantities presented in the Grading Frame are based on the stations between balance points. For information on determining balance points, see Section 5.2.4.

When using computer programs, see the instructional manuals to determine the appropriate procedures for calculating earthwork quantities.

5.2.2 Manual Computations

The following presents procedures for determining earthwork quantities manually:

1. Computation Sheets. Figures 5.2A through 5.2D illustrate a sample problem for manually calculating earthwork quantities on the Department's computation sheet. A blank computation sheet is provided at the end of this section. Note that the example illustrated in Figure 5.2A through 5.2D includes rock excavation which requires a swell factor to be applied to the excavated material. See Section 5.2.6 for guidance on shrink/swell factors with excavations. Complete the first five columns of the sheet (i.e., grades, vertical curve data, grade elevations, stations and distance between stations) during the process of computing grades. The remaining columns are used for documenting cross-section areas, volumes between cross sections, shrink and swell factors and mass curve data used for plotting the mass diagram. Projects requiring a mass diagram typically should be prepared using the computer. Compute quantity sections for each terrain station.

EARTHWORK COMPUTATIONS

EXAMPLE CRITERIA:
SHRINK FACTOR = 30 %
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
2ND RUN-20% SWELL APPLIED FROM STA. 2 00 TO STA. 2+80
AND SHRINK APPLIED IN APPROPRIATE AREAS

PROJECT NO. EXAMPLE LOCATION ______ SHEET ____ OF ____ SHEETS
DESIGNER ______ DESIGN DATE ______ CHECK DATE ______

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE FEET: CUT AREA	CUT DOUBLE AREA	FILL AREA	FILL DOUBLE AREA	VOLUME IN CUBIC YARDS: EXCAVATION ACTUAL	SWELL FACTOR	ADJ. EXC.	EMBANKMENT ACTUAL	SHRINK FACTOR	EMB +	MASS CURVE DATA: CUT +	FILL −	M	
			0+00		0		0										0	
				65.62		4306		323	5233			393			4840			
			0+65.62		4306		323										+4840	
				65.61		9419		1399	11444			1700			9744			
			1+31.23		5113		1076										+14584	
				65.62		7373		13132	8960			15958				6998		
			1+96.85		2260		12056										+7586	
				65.62		2260		24327	2746			29562				26816		2+15.41
			2+62.47		0		12271										-19230	
				65.61		538		21313	654			25895				25241		
			3+28.08		538		9042										-44471	
				65.62		1238		14532	1504			17659				16155		3+87.14
			3+93.70		700		5490										-60626	
				65.62		1884		7750	2289			9418				7129		
			4+59.32		1184		2260										-67755	
				55.77		2314		3337	2390			3445				1055		
			5+15.09		1130		1076										-68810	
				75.46		2529		1076	3534			1504			2030			59128 cyds HAULED BACK
			5+90.55		1399		0										-66780	
				65.62		6297		0	7652			0			7652			
			6+56.17		4898		0										-59128	
				131.23		17815		0	43294	20 %	51953	0		*127139	51953			
			7+87.40		12917		0										-7175	
				131.24		26049		323	63309	20 %	75971	785			75186			7+99.92
			9+18.64		13132		323										+68011	
				98.42		17761		1184	32371			2158			30213			
			10+17.06		4629		861										+98224	
				32.81		6136		2045	3728			1243			2485			
			10+49.87		1507		1184										+100709	
				65.62		1615		3337	1963			4055				2092		68011cyds HAULED AHEAD
			11+15.49		108		2153										+98617	
				65.61		216		4844	262			5885				5623		
			11+81.10		108		2691										+92994	
				65.42		2261		4898	2739			5934				3195		
			12+46.72		2153		2207										+89799	
				65.67		4952		4037	6022			4909			1113			
			13+12.39		2799		1830										+90912	
				163.99		5705		6674	17325			20268				2943		14+69.82
			14+76.38		2906		4844										+87969	
				164.04		2906		11625	8828			35314				26486		
			16+40.42		0		6781										+61483	
				164.04		0		12163	0			36948				36948		
			18+04.46		0		5382										+24535	18+97.01
				164.04		0		14316	0			43489				43489		
			19+68.50		0		8934										-18954	

* SUM OF ADJUSTED ROCK EXCAVATION

EXAMPLE EARTHWORK COMPUTATION SHEET
(First Run)

Figure 5.2A (US Customary)

EARTHWORK COMPUTATIONS

EXAMPLE CRITERIA:
SHRINK FACTOR = 30%
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
1ST RUN-20% SWELL APPLIED FROM STA. 2+00 TO STA. 2+80 ONLY

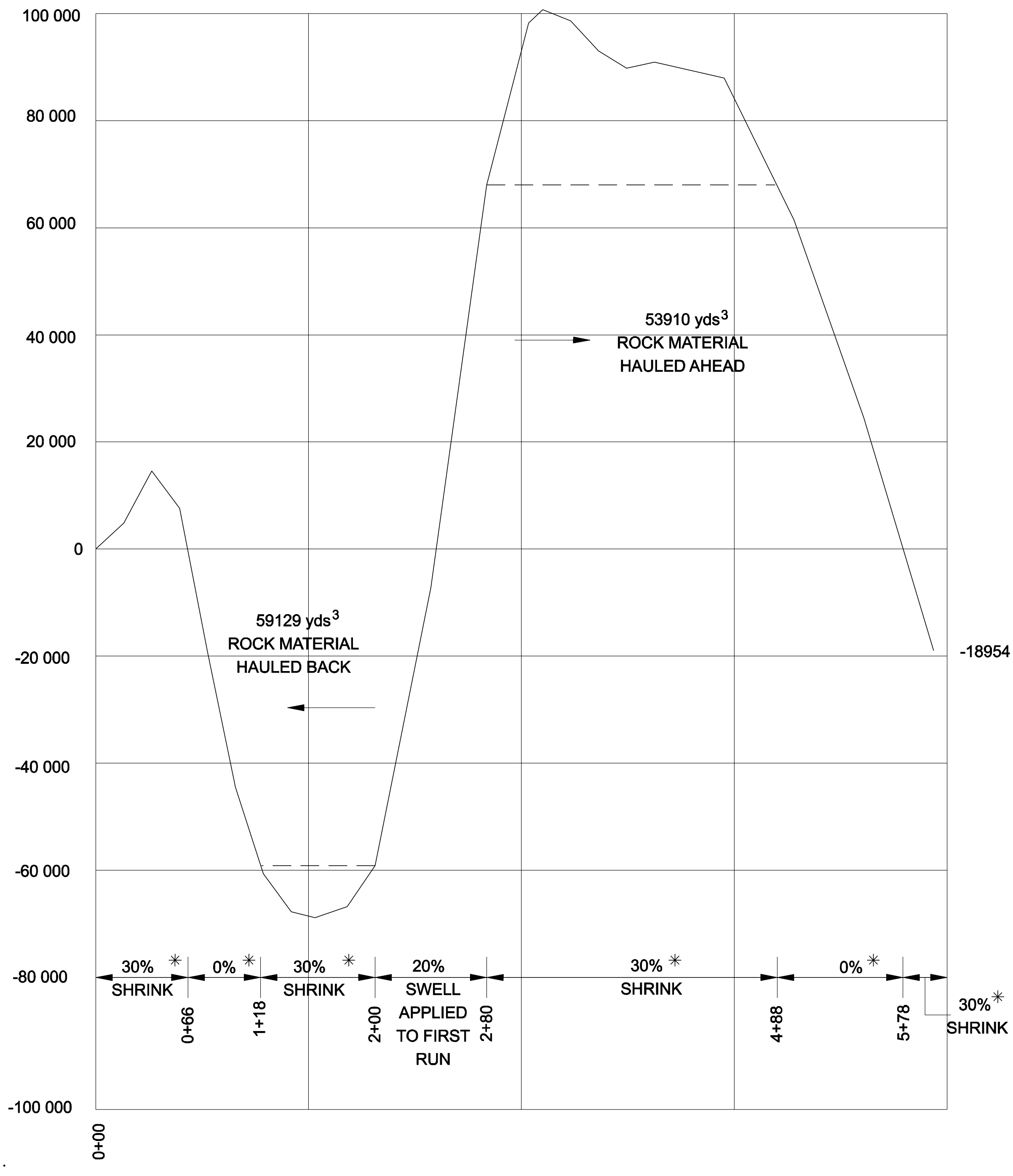
PROJECT NO. EXAMPLE LOCATION ______ SHEET ____ OF ____ SHEETS
DESIGNER ______ DESIGN DATE ______ CHECK DATE ______

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS: CUT AREA	CUT DOUBLE AREA	FILL AREA	FILL DOUBLE AREA	VOLUME IN CUBIC METERS: EXCAVATION ACTUAL	SWELL FACTOR	ADJ. EXC.	EMBANKMENT ACTUAL	SHRINK FACTOR	EMB +	MASS CURVE DATA: CUT +	FILL -	M	
			0+00		0		0										0	
				20		400		30	4000			300			3700			
			+20		400		30										+3700	
				20		875		130	8750			1300			7450			
			+40		475		100										+11 150	
				20		685		1220	6850			12 200				5350		
			+60		210		1120										+5800	
				20		210		2260	2100			22 600				20 500		
			+80		0		1140										-14 700	0+66
				20		50		1980	500			19 800				19 300		
			1+00		50		840										-34 000	
				20		115		1350	1150			13 500				12 350		
			+20		65		510										-46 350	1+18
				20		175		720	1750			7200				5450		
			+40		110		210										-51 800	
				17		215		310	1828			2635				807		
			+57		105		100										-52 607	
				23		235		100	2703			1150			1553			
			+80		130		0										-51 054	
				20		585		0	5850			0			5850			
			2+00		455		0										-45 204	45 204 m^3 HAULED BACK
				40		1655		0	33 100	20%	39 720	0		*97 200	39 720			
			+40		1200		0										-5484	
				40		2420		30	48 400	20%	58 080	600			57 480			
			+80		1220		30										+51 996	2+44
				30		1650		110	24 750			1650			23 100			
			3+10		430		80										+75 096	51 996 m^3 HAULED AHEAD
				10		570		190	2850			950			1900			
			+20		140		110										+76 996	
				20		150		310	1500			3100				1600		
			+40		10		200										+75 396	
				20		20		450	200			4500				4300		
			+60		10		250										+71 096	
				20		210		455	2100			4550				2450		
			+80		200		205										+68 646	
				20		460		375	4600			3750			850			
			4+00		260		170										+69 496	
				50		530		620	13 250			15 500				2250		
			+50		270		450										+67 246	
				50		270		1080	6750			27 000				20 250		
			5+00		0		630										+46 996	4+88
				50		0		1130	0			28 250				28 250		
			+50		0		500										+18 746	
				50		0		1330	0			33 250				33 250		
			6+00		0		830										-14 504	5+78

* SUM OF ADJUSTED ROCK EXCAVATION

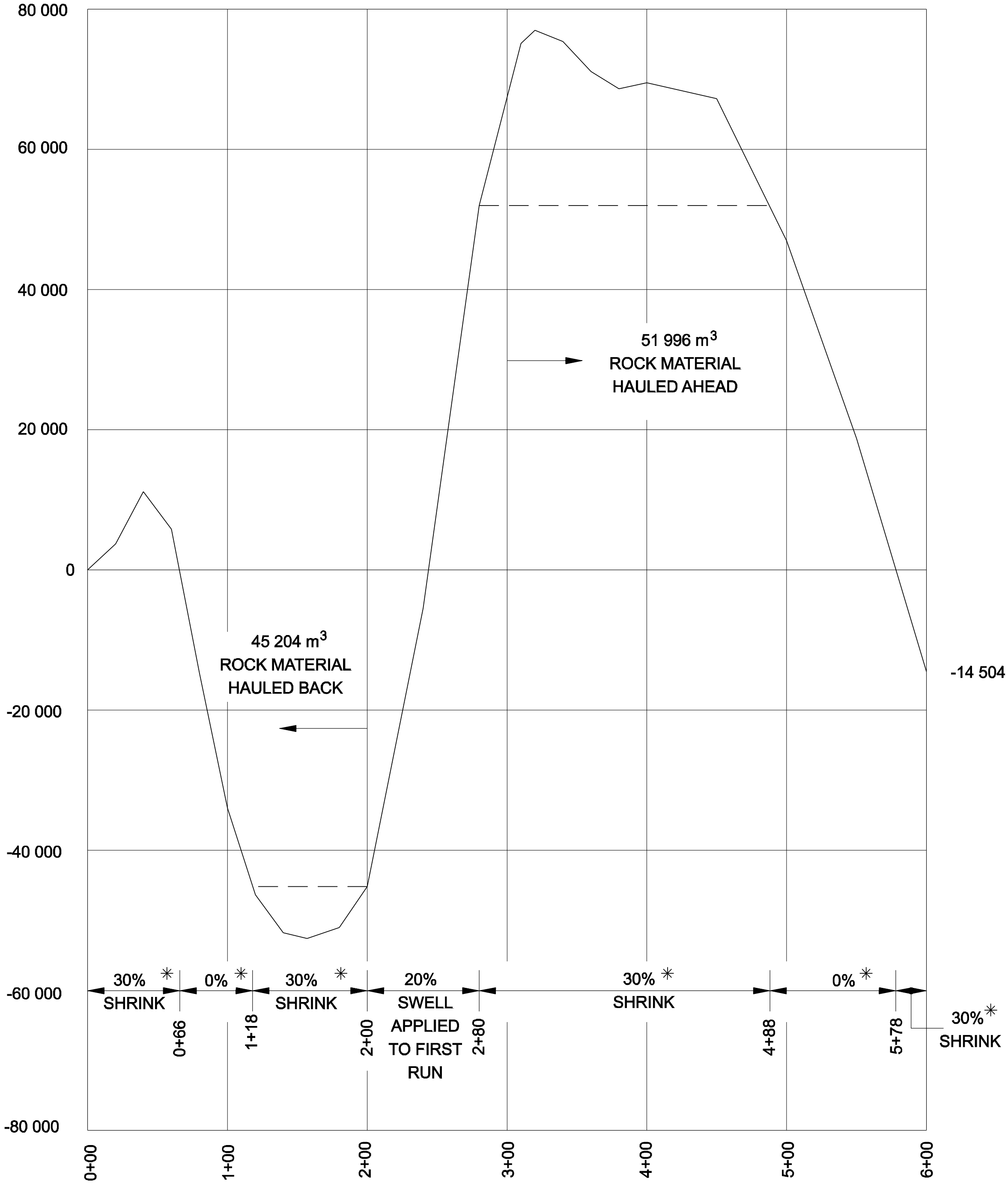
EXAMPLE EARTHWORK COMPUTATION SHEET
(First Run)

Figure 5.2A (Metric)



* *As a result of the first run's mass diagram, the locations where to apply the shrink, no shrink or swell factors can be determined. Apply all shrink and swell factors to the second run.*

MASS DIAGRAM
(First Run: With Only Swell Factor Applied)
Figure 5.2B (US Customary)



* *As a result of the first run's mass diagram, the locations where to apply the shrink, no shrink or swell factors can be determined. Apply all shrink and swell factors to the second run.*

MASS DIAGRAM
(First Run: With Only Swell Factor Applied)

Figure 5.2B (Metric)

EARTHWORK COMPUTATIONS

EXAMPLE CRITERIA:
SHRINK FACTOR = 30 %
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
2ND RUN-20% SWELL APPLIED FROM STA. 2 00 TO STA. 2+80
AND SHRINK APPLIED IN APPROPRIATE AREAS

PROJECT NO. EXAMPLE LOCATION SHEET ____ OF ____ SHEETS
DESIGNER DESIGN DATE CHECK DATE

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE FEET: CUT AREA	CUT DOUBLE AREA	FILL AREA	FILL DOUBLE AREA	VOLUME IN CUBIC YARDS: EXCAVATION ACTUAL	SWELL FACTOR	ADJ. EXC.	EMBANKMENT ACTUAL	SHRINK FACTOR	EMB +	MASS CURVE DATA: CUT +	FILL −	M	
			0+00		0		0										0	
				65.62		4306		323	5233			393	30%	511	4722			
			0+65.62		4306		323										+4722	
				65.61		9419		1399	11444			1700		2210	9234			
			1+31.23		5113		1076										+13956	
				65.62		7373		13132	8960			15958		20745		11785		
			1+96.85		2260		12056										+2171	
				65.62		2260		24327	2746			29562	0%	11529 20693		29476		2+01.68
			2+62.47		0		12271										-27305	
				65.61		538		21313	654			25895		25895		25241		
			3+28.08		538		9042										-52546	
				65.62		1238		14532	1504			17659		15893 2296		16685		
			3+93.70		700		5490										-69231	
				65.62		1884		7750	2289			9418	30%	12243		9954		
			4+59.32		1184		2260										-79185	
				55.77		2314		3336	2390			3445		4479		2089		
			5+15.09		1130		1076										-81274	
				75.46		2529		1076	3534			1504		1955	1579			
			5+90.55		1399		0										-79695	
				65.62		6297		0	7652			0		0	7652			
			6+56.17		4898		0										-72043	
				131.23		17815		0	43294	20%	51952	0	0%	0	51952			
			7+87.40		12917		0										-20091	
				131.24		26049		323	63309		75971	785		785	75186			8+22.47
			9+18.64		13132		323										+55095	
				98.42		17761		1184	32371			2158	30%	2805	29566			
			10+17.06		4629		861										+84661	
				32.81		6136		2045	3728			1243		1616	2112			
			10+49.87		1507		1184										+86773	
				65.62		1615		3337	1963			4055		5272		3309		
			11+15.49		108		2153										+83464	
				65.61		216		4844	262			5885		7651		7389		
			11+81.10		108		2691										+76075	
				65.42		2261		4898	2739			5934		7714		4975		
			12+46.72		2153		2207										+71100	
				65.62		4952		4037	6018			4906		6378		360		
			13+12.34		2799		1830										+70740	
				164.04		5705		6674	17331			20274		26356		9023		
			14+76.38		2906		4844										+61717	
				164.04		2906		11625	8828			35314		34889 8476		34537		
			16+40.42		0		6781										+27180	
				164.04		0		12165	0			36955	0%	36955		36955		
			18+04.46		0		5382										+9768	
				164.04		0		14316	0			43489		24356 24872		49228		17+61.09
			19+68.50		0		8934										-59003	
													30%					

EXAMPLE EARTHWORK COMPUTATION SHEET
(Second Run)

Figure 5.2C (US Customary)

EARTHWORK COMPUTATIONS

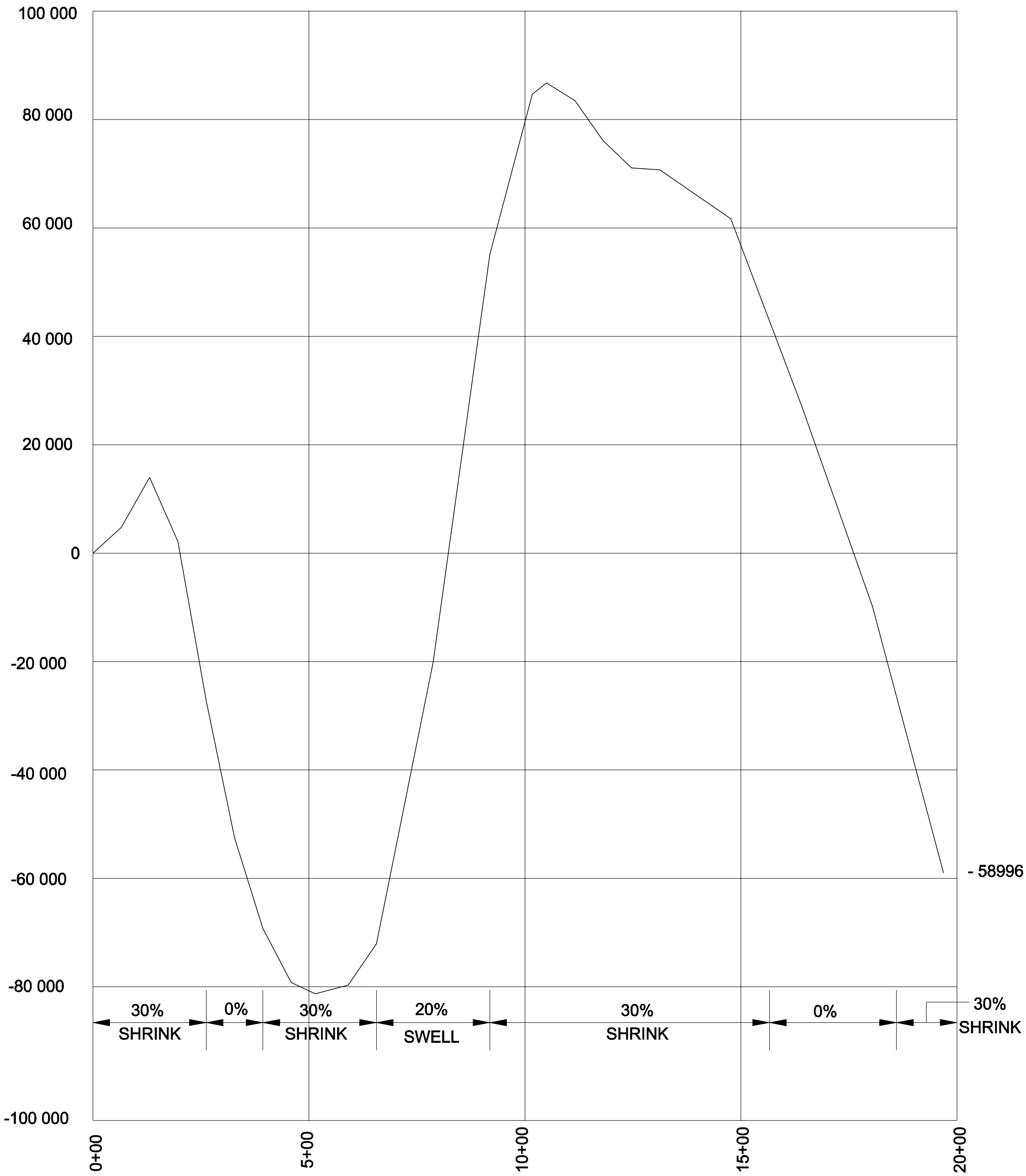
EXAMPLE CRITERIA:
SHRINK FACTOR = 30 %
EXCEPT STA. 2+00 TO 2+80 = 20% SWELL
2ND RUN-20% SWELL APPLIED FROM STA. 2 00 TO STA. 2+80
AND SHRINK APPLIED IN APPROPRIATE AREAS

PROJECT NO. EXAMPLE LOCATION ______ SHEET ____ OF ____ SHEETS
DESIGNER ______ DESIGN DATE ______ CHECK DATE ______

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS – CUT – AREA	CUT – DOUBLE AREA	FILL – AREA	FILL – DOUBLE AREA	VOLUME IN CUBIC METERS – EXCAVATION – ACTUAL	EXCAVATION – SWELL FACTOR	EXCAVATION – ADJ. EXC.	EMBANKMENT – ACTUAL	EMBANKMENT – SHRINK FACTOR	EMB +	MASS CURVE DATA – CUT +	MASS CURVE DATA – FILL −	M	
			0+00		0		0										0	
				20		400		30	4000			300	30 %	390	3610			
			+20		400		30										+3610	
				20		875		130	8750			1300		1690	7060			
			+40		475		100										+10 670	
				20		685		1220	6850			12 200		15 860		9010		
			+60		210		1120										+1660	
				20		210		2260	2100			22 600	0 %	8814 15 820		22 534		0+61
			+80		0		1140										-20 874	
				20		50		1980	500			19 800		19 800		19 300		
			1+00		50		840										-40 174	
				20		115		1350	1150			13 500		12 150 1755		12 755		
			+20		65		510										-52 929	
				20		175		720	1750			7200		9360		7610		
			+40		110		210										-60 539	
				17		215		310	1828			2635	30 %	3426		1598		
			+57		105		100										-62 137	
				23		235		100	2703			1150		1495	1208			
			+80		130		0										-60 929	
				20		585		0	5850			0		0	5850			
			2+00		455		0										-55 079	
				40		1655		0	33 100	20 %	39 720	0	0 %	0	39 720			
			+40		1200		0										-15 359	
				40		2420		30	48 400		58 080	600		600	57 480			2+51
			+80		1220		30										+42 121	
				30		1650		110	24 750			1650		2145	22 605			
			3+10		430		80										+64 726	
				10		570		190	2850			950		1235	1615			
			+20		140		110										+66 341	
				20		150		310	1500			3100		4030		2530		
			+40		10		200										+63 811	
				20		20		450	200			4500	30 %	5850		5650		
			+60		10		250										+58 161	
				20		210		455	2100			4550		5915		3815		
			+80		200		205										+54 346	
				20		460		375	4600			3750		4875		275		
			4+00		260		170										+54 071	
				50		530		620	13 250			15 500		20 150		6900		
			+50		270		450										+47 171	
				50		270		1080	6750			27 000		26 676 6480		26 406		
			5+00		0		630										+20 765	
				50		0		1130	0			28 250	0 %	28 250		28 250		
			+50		0		500										-7485	
				50		0		1330	0			33 250		18 620 19 019		37 639		5+37
			6+00		0		830										-45 124	
													30 %					

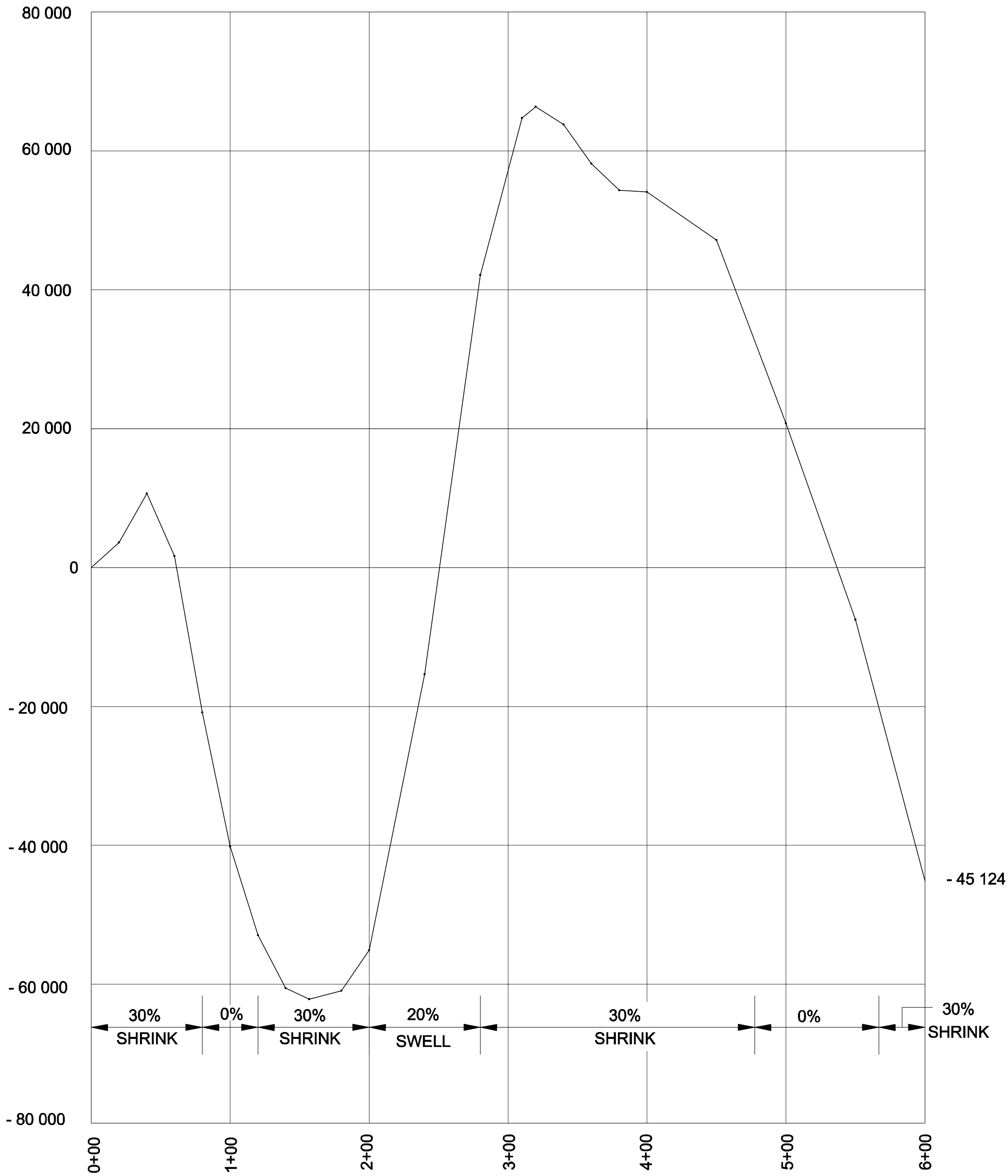
EXAMPLE EARTHWORK COMPUTATION SHEET
(Second Run)

Figure 5.2C (Metric)



MASS DIAGRAM
(Second Run: With All Shrink and Swell Factors Applied)

Figure 5.2D (US Customary)



MASS DIAGRAM
(Second Run: With All Shrink and Swell Factors Applied)

Figure 5.2D (Metric)

2. Area Definitions. The end areas that are used to compute the quantities are defined by the ground lines and typical section template (see Figure 5.2E). Where special borrow is required, compute fill areas to the bottom of the special borrow as shown in Illustration (B) of Figure 5.2E. Determine the area of cut and fill for each cross section using CADD. Record the cut and fill areas for each cross section in the "AREA" column of the Computation Sheet. The "DOUBLE AREA" column shows the sum of adjacent cross-section areas.

3. Volume Computations. Determine volumes for excavation and embankment using the average-end-area formula:

US Customary

$$V = \frac{A_1 + A_2}{2} x \frac{D}{27}$$

Metric

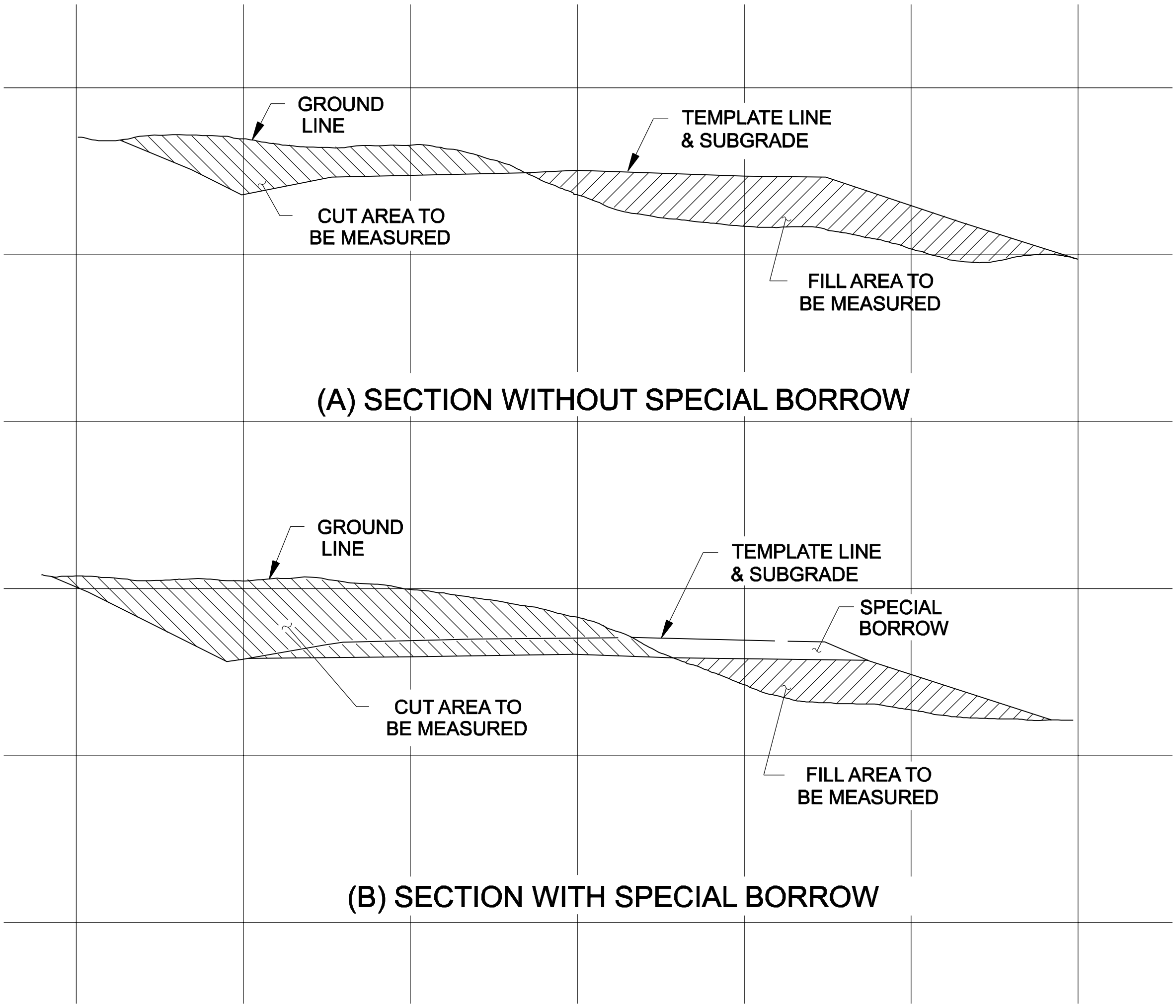
$$V = \frac{A_1 + A_2}{2} xD \qquad \text{(Equation 5.2-1)}$$

Where:

V	=	volume, yd^3 (m^3)
$A_1 + A_2$	=	sum of cut or fill end areas of adjacent sections (Double Area), ft^2 (m^2)
D	=	distance between sections, ft (m)

Record these values in the appropriate excavation or embankment "ACTUAL" columns on the Computation Sheet. The "EMB +" column provides the embankment quantity multiplied by the appropriate shrink factor(s). Enter the difference between the "EMB +" and "ACTUAL" Excavation columns in either the "CUT +" or "FILL -" columns for Mass Curve Data. If the "EMB +" is greater than the "ACTUAL" excavation volume, enter the difference in the "FILL -" column. If the "ACTUAL" excavation volume is greater than the "EMB +" volume, enter the difference in the "CUT +" column. The "ADJ. EXC." column is the excavation column multiplied by the appropriate swell factor(s). Enter the difference between the "ADJ. EXC." and the "ACTUAL" embankment in the Mass Curve Data in either the "CUT +" column, if excavation is greater, or in the "FILL -" column, if embankment is greater.

The shrink and swell factor used should be recorded on the computation sheet. Total volumes for the sheet should be shown on the bottom of each Computation Sheet.



AREA DEFINITIONS

Figure 5.2E

5.2.3 Shrink and Swell Factors

Adjust excavation and/or embankment quantities, calculated either manually or by the computer, by the appropriate shrink and/or swell factor(s). The use of more than one factor for a project is often necessary to describe the characteristics of the excavated material. However, do not apply both shrink and swell factors to the same material. The factors used in the calculations will depend on the soil type, quantity to be moved and judgment. The applicable factors to be used in the calculations are provided by the District. Also present these factors on the mass diagram.

5.2.4 Balancing

For most large projects, it is highly desirable to provide an earthwork balance for the project (i.e., excavation equals adjusted embankment quantities). However, due to the degree of accuracy of shrink/swell factors and the nature of grading work, do not make an extensive effort to produce an exact zero earthwork balance. Typically, a project is considered balanced if the borrow/excess quantity is within 3% of the total excavation quantity. If the earthwork is balanced within 3%, show the borrow or excess quantity with an asterisk (*) and a note stating “Not a bid item - for informational purposes only.” A small amount of excess is preferred over a small amount of borrow on a project because, in most cases, a disposal site for a small excess quantity can be easily found. A small amount of borrow will likely be bid at an inflated price. Unbalanced projects will require the contractor to haul extra material (e.g., borrow) or remove excess material (e.g., excavation) from the project, which will typically increase construction costs. Balancing within the project limits can be accomplished by revising the profile grade line, revising cut and fill slopes, daylighting sections, revising ditch profiles, etc. To determine if balancing is appropriate for a project, consider the following guidelines:

1. New Construction/Reconstruction Projects. Make every reasonable effort to balance the project.

2. Overlay and Widening Projects. Determine the need for balancing the project on a project-by-project basis.

3. Other Projects. For urban projects, interchange projects and pavement preservation projects, it is generally impractical to provide a balanced grading design. Therefore, it will not be necessary to balance earthwork quantities on these project types.

It is generally not cost effective to balance a project over long distances. On long projects, provide several intermediate balance points. Generally, balance sections should not exceed 2 miles (3 km) and should not include bridges within the balance limits.

5.2.5 Mass Diagram

On projects where the grading is bid as unclassified excavation, prepare a mass diagram to illustrate how the project will be balanced.

To better understand the application of a mass diagram, consider the following guidelines:

1. Curve. The mass diagram curve illustrates a cumulative, algebraic summation of the excavation and embankment quantities, typically from the start of the project. A rising curve in the direction of summation indicates excavation exceeds embankment, and a falling curve indicates embankment exceeds excavation. Inflection points (i.e., curve crests and sags) represent points where the net earthwork changes from a cut to a fill or vice versa. The horizontal distance on the mass diagram represents the horizontal distance on the ground in stations. The vertical distance represents the net accumulation of earthwork volume in cubic meters.

2. Balance Line. The balance line is any horizontal line which intersects the mass summary curve in at least two places. This indicates that the excavation and embankment quantities are balanced between the two intersecting points. These intersection points are called balance points. For most projects, the balance line is typically started at zero at the beginning of the project.

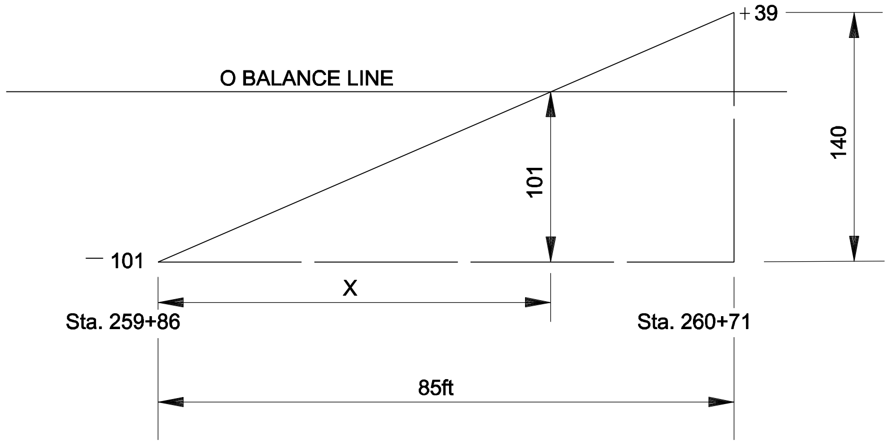
3. Balance Points. Once the grades have been finalized and the earthwork has been balanced, compute the balance points and the earthwork quantities for summarization. It is not necessary to compute earthwork quantities for each balance point. Several small balance points may be combined within distances of approximately 1000’ (300 m). Where a balance point falls between the stations listed on the computation sheet, compute the stationing using a straight-line interpolation; see Example 5.2-1. Round the stationing to the nearest meter.

4. Borrow/Excess. As stated in Section 5.2.4, long distances between balance points or over bridges are generally not cost effective. Also, it may be necessary to adjust the balance line at funding divisions to indicate the amount of material moved for the particular section. To balance a section, the balance line may need to be adjusted up or down. Downward adjustments in the balance line indicate the need for borrow, and upward adjustments indicate excess material. Note the amount of borrow or excess next to the vertical balance line. The location of the borrow pit or waste disposal location will typically be determined by the contractor.

* * * * * * * * *

Example 5.2-1

Given:



Problem: Find the stationing of the balance point between stations 259+86 and 260+71.

Solution: Use straight-line interpolation.

Stationing of Balance Point = 259+86 Plus " X " feet

$$X = \frac{101}{140} x85\,ft$$

$$X = 61\,ft$$ (round to the nearest foot)

Stationing of Balance Point = 259+86 + 61 = 260+47

* * * * * * * * * *

5. Haul. Calculate the amount of haul by determining the volume of material that will be moved from the center of the excavation to the center of the embankment between two balance points. Haul is typically calculated for informational purposes and is not a bid item. To compute haul, calculate the unit haul Mile Yards per Square Inch (m^3 • km) represented by one grid unit and divide by the actual area Square Inches (m^2) of the grid unit. This produces a ratio of unit haul per unit area Cubic Yards x Mile Yards/Square Inches (m^3 • km/m^2) at the specified scale. Multiply this ratio by the mass area Square Inches (m^2) to produce the haul Cubic Yards x Miles (m^3 • km) for that mass area as shown in Equation 5.2-1.

$$\text{Mile Yards/Square Inch (MY/IN}^2\text{)} = \frac{\text{Station/Inch x Cubic Yards/Inch}}{52.8}$$

US Customary

$$Haul = \left[\left(\frac{H.G.V. x V.G.V.}{52.8} \right) \div G.A. \right] x\ M.A.$$

Metric

$$Haul = \left[\left(\frac{H.G.V. x V.G.V.}{1000} \right) \div G.A. \right] x\ M.A. \qquad \text{(Equation 5.2-1)}$$

Where:

$Haul$ = the amount of material moved, yds^3 • m (m^3 • km)

$H.G.V.$ = horizontal grid value on horizontal axis of each unit of grid, Inch (m)

$V.G.V.$ = vertical grid value on vertical axis of each unit of grid, yrs^2 (m^3)

$G.A.$ = measured area of one grid unit, inch^2 (m^2)

$M.A.$ = measured area bounded by mass curve and balance line between balance points, inch^2 (m^2)

6. Quantities. Show the amount of excavation, embankment and haul on the mass diagram between each set of balance points. Also present the excavation and embankment quantities in the Grading Frame on the Summary Sheet.

5.2.6 Unclassified Excavation

The following presents the procedures for recording unclassified excavation quantities on the Grading and Additional Grading Frames:

1. Shrink/Swell Factors. Use the following procedures to adjust the excavation and embankment quantities by the appropriate shrink or swell factors:

   a. Soil. Adjust the actual embankment volumes by the appropriate shrink factor and show the results in the “EMB+” column on the Grading Frame.

   b. Rock. Depicting the adjusted excavation (swelled) volumes for rock in the mass curve provides a truer representation of the distribution of grading quantities. Computing earthwork quantities for projects having rock (swell factors) typically requires two earthwork runs. The first run is used to determine the quantity of rock excavation and the locations for applying shrink factors to embankments. For this first run, apply the appropriate swell factor to the actual excavation within the station limits of designated rock cut only. Do not apply a shrink factor to the remainder of the project. Produce a preliminary mass diagram from the first run.

From the mass diagram, determine the direction the rock material will be hauled and the locations to apply the appropriate shrink factor. In the areas where rock material will be used to construct the embankment, the actual volumes are not adjusted.

The second run will have both factors, swell in the rock cut areas and shrink in the areas of embankments not being constructed with rock. See Figures 5.2A through 5.2D for example computations and mass diagrams of rock excavation.

Output from the second run is shown in the Grading Frame. Show both the actual unclassified excavation and the adjusted unclassified excavation quantities on the Grading Frame. The total actual unclassified excavation is used for bidding purposes. The adjusted unclassified excavation is used to determine the excess or borrow quantities.

2. Additional Grading. Additional grading is the excavation and embankment required for constructing the items of work in addition to the mainline roadway template required for the project. Embankment quantities should always be included in the roadway quantities. Excavation quantities fall into two categories as follows:

   a. Suitable Material. If the material is suitable, include the quantity in the mainline roadway quantities. Material is considered suitable if it consists of an acceptable soil type and the quantity is large enough to make handling practical. Examples include approaches, widening, slope flattening, etc.

   b. Unsuitable Material. If the material is unsuitable, designate the quantity as an “ADD. EXC.” item but do not include this item in the mainline roadway quantities. Material is considered unsuitable if it consists of unacceptable soil types and/or quantities too small to make handling practical. Examples include material near inlet and outlet ditches, existing ditches graded to drain, etc.

Do not use the additional excavation item (i.e., “ADD. EXC.”) as a catch-all for late entries. This practice is a carryover from when earthwork quantities and the mass diagram were produced by hand. Revisions at that time were very time consuming. With computers and CADD, revisions to grading quantities and the mass diagram can be performed in a relatively short period of time. Items with significant volumes that are added late in the design phase require inclusion in both the mainline roadway quantities and the mass diagram to reflect the changes such quantities have on balances, haul, volumes, etc.

3. Topsoil Replacement. Topsoil replacement is the volume of embankment required to fill the void left after the topsoil has been removed. This quantity mathematically re-establishes the ground line to its original state prior to topsoil removal. Adjust topsoil replacement quantities by employing the same shrink factor used for mainline grading quantities in the area that the topsoil was removed. Include topsoil replacement in the roadway quantities for all projects. This results in representing topsoil replacement as an embankment or borrow quantity. Show the project total for topsoil replacement as an "EMB+" quantity in the "INCLUDED IN ROADWAY" column of the Additional Grading Frame.

4. Subexcavation. On reconstruction projects, subexcavation is generally a specified depth of excavation below subgrade in existing fill or natural ground. Always specify subexcavation depth from the top of the subgrade elevation unless an unusual circumstance justifies another reference. Typically, this material can be excavated using the equipment and procedures normally used for unclassified excavation. If the material is unstable, the subexcavation also includes the disposal of the material. Material is considered unstable if it contains saturated soils, mixtures of soils, and/or organic matter that is unsuitable for foundation material. Examples of unstable material include swelling clays or silty soils having low support value or subject to frost heaving.

   An unclassified excavation quantity is used to remove subexcavated material and either place it in embankments or dispose of it. If the material may be used for embankments, include the quantities in the earthwork run and denote the quantities shown in the Subexcavation Frame with an asterisk ("*") and a note stating "Included in roadway quantities." Record these same quantities in the "INCLUDED IN ROADWAY QUANTITIES — EXCAVATION" column of the Additional Grading Frame. If the material is to be disposed, record the quantity in the "UNCL. EXC." column of the Subexcavation Frame only. This quantity should not be included in the Additional Grading Frame or the earthwork run.

5. Subexcavation Replacement. If subexcavation is not replaced with special material, include the adjusted quantities in the earthwork run and show these quantities in the "INCLUDED IN ROADWAY" column of the Additional Grading Frame. If a special material is provided, show the actual quantity as special borrow in the Subexcavation Frame.

6. Roadbed Compaction. Roadbed compaction is usually not a bid item, unless otherwise determined during the plan review process. It is utilized to ensure proper embankment construction. The roadbed compaction quantity is the total volume (cubic yd or m^3) of all embankment material (e.g., roadway, approaches, berms) plus a volume determined from the project length, the subgrade width and an 8" (0.2 m) compacted depth either of natural ground, in fill sections, or of

subgrade in cut sections. If required as a bid item, calculate roadbed compaction as follows:

US Customary	Metric
C = (W x L x D/12)/27 + EMB+	C = (W x L x D) + EMB+

Where:

W = Width of subgrade, ft (m)

L = Length of project, ft (m)

D = Compacted depth = 8” (0.2 m)

C = Roadbed compaction, cubic yd (m^3)

EMB+ = Adjusted quantity of material placed in the roadway, cubic yd (m^3). If the subgrade width varies, compute quantities for each width. Show the total quantity on the Grading Frame.

5.2.7 Embankment-in-Place Projects

Only use the embankment-in-place item on projects with grading quantities less than 25,000 cubic yd (20 000 m^3) and where embankment exceeds excavation. For all other projects, designate the grading quantities as unclassified excavation. The following presents the procedures for recording the embankment-in-place quantities in the Grading and Additional Grading Frames:

1. Shrink/Swell Factors. Do not adjust the excavation or embankment quantities with shrink or swell factors.

2. Additional Grading Frame. Show both the embankment and excavation of suitable material quantities in the Additional Grading Frame. Suitable material is defined in Section 5.2.6, Item 2. Add the totals from the Additional Grading Frame to the Grading Frame.

3. Minor Excavation. Additional grading items consisting of small excavation quantities and/or excavation of unsuitable material will be paid as embankment in place. Unsuitable material is defined in Section 5.2.6, Item 2. Show these excavation quantities in the “ADD. EMB. IN PLACE” column of the Additional Grading frame and total. This quantity is not used to determine the amount of borrow required for the project.

4. Topsoil Replacement. Show the project total for topsoil replacement as an "EMB. IN PLACE" quantity in the Grading Frame. However, it should not be adjusted for shrinkage.

5. Subexcavation. An embankment-in-place quantity reflects the removal of subexcavated material that is either placed in embankments or disposed of. Show the quantity as a line item in the Grading Frame. Denote the total of the Subexcavation Frame with an asterisk ("*") and a note stating "Included in the Grading Frame."

6. Subexcavation Replacement. If subexcavation is not replaced with special material, an embankment-in-place quantity is required to replace the subexcavated material. Denote the total of the Subexcavation Frame with an asterisk ("*") and a note stating "Included in the Grading Frame," and show the quantity as a line item in the Grading Frame. If a special material is required, show the actual quantity as a special borrow item in the Subexcavation Frame.

7. Mass Diagram. A mass diagram is not required for embankment-in-place projects.

8. Roadbed Compaction. Roadbed compaction is not a bid item for embankment-in-place projects.

5.2.8 Miscellaneous Considerations

In addition to the above, consider the following when determining earthwork quantities:

1. Street Excavation. Street excavation is typically used on urban projects and consists of the excavation and removal of all material within the specified template. Street excavation should be utilized when the designer anticipates that material is present that is not normally encountered in typical unclassified excavation (e.g. abandoned pipe, old foundations).

2. Digout Excavation. The District Office and the Geotechnical Section are responsible for determining the need for and location of digouts. The designer is responsible for incorporating their recommendations onto the plans. The excavation and disposal of existing surfacing and subgrade is measured and paid for by the cubic yard (cubic meter) of "Digout Excavation." If a special material is required for a fill portion of the digout replacement, it is measured and paid for as special borrow or as select backfill as specified by the Geotechnical Section and shown in the Digout Frame. If it is not replaced with special material, the fill is paid for as follows:

a. Unclassified Excavation Projects. For unclassified excavation projects, the replacement fill is entered as EMB+ quantity in the earthwork run and is not measured for payment. The digout replacement quantities should be shown in the Additional Grading Frame. Denote the "DIGOUT REPLACEMENT" column in the Digout Frame with an asterisk ("*") and a note stating "Included in the roadway quantities."

b. Embankment-in-Place Projects. For embankment-in-place projects, the replacement fill is paid for as embankment-in-place. Add a line item to the Grading Frame, and denote the DIGOUT REPLACEMENT column of the Digout Frame with an asterisk ("*") and a note stating "Included in the Grading Frame."

Surfacing is normally replaced with new surfacing material. Include these quantities in the Additional Surfacing Frame. Note that digouts are not provided on new construction/reconstruction projects. For these projects, the removal of unsuitable material below subgrade (i.e., in cut sections) and natural ground (i.e., in embankment sections) is paid for as either unclassified excavation or muck excavation, depending on the material and equipment used. Where digouts are required, include a detail showing all removal and replacement thicknesses in the plans.

3. <u>Muck Excavation</u>. Muck excavation is both the removal and disposal of unstable material below either the subgrade elevation, in cut sections, or the natural ground line, in embankment sections. Specify muck excavation if the unstable material cannot be excavated using the same equipment and methods as for unclassified excavation.

4. <u>Unclassified Channel Excavation</u>. Unclassified channel excavation is the excavation and disposal of all material for either the construction of new water courses and channels or the modification (e.g., widening, deepening, straightening) of existing channels. Unclassified channel excavation is typically specified when the excavated material is not used to construct roadway embankments.

5. <u>Unclassified Borrow</u>. Unclassified borrow for embankment construction is contractor furnished material excavated from outside the right-of-way or construction easement areas. Sources for this material must be approved by the Department and meet current environmental and cultural resource preservation regulations. Note that construction permits requested solely for the purpose of obtaining material to construct embankments are of questionable legality. Therefore, slope flattening beyond the right-of-way limit is not an acceptable practice for balancing a project. Show the amount of unclassified borrow in the

Grading Frame and mass diagram. It should be noted that the unclassified borrow is assumed to have the same shrink/swell factor and structural value as the unclassified excavation on the project. If the designer believes that the values for the unclassified borrow will differ significantly from the unclassified excavation, these values should be reviewed at the Alignment & Grade Review or the PIH.

6. Special Borrow. Special borrow for embankment construction is material that has a specific minimum R-value or soils-class designation. Typically, special borrow is contractor furnished material excavated from a Department-approved source outside the right-of-way or construction easement areas. Use the following guidelines where special borrow is required:

   a. Reducing Surfacing Section Thickness. To reduce a surfacing section's depth and cost, its design may be based on a minimum R-value, for the top 2' (0.6 m) of subgrade, that is higher than that of readily available material. This practice frequently requires the use of special borrow. In this case, for the top 2' (0.6 m) of subgrade, calculate the quantity of special borrow required from a Department-approved source rather than relying on a special provision to specify the material's minimum R-value or soils-class designation. The use of a special provision, in this case, generally results in a cost increase and requires the contractor to selectively grade the project to meet the requirements. Without specific guidance, the contractor will estimate the quantity and source of the special borrow material, and any uncertainties will tend to produce overly conservative estimates and higher bid prices from the contractor. If special borrow is recommended to reduce surfacing section thickness, the special borrow may be treated as part of the surfacing section or included in the subgrade. Refer to Section 4.3.6 for guidance as to how the special borrow should be shown. Where special borrow that is used to reduce the surfacing section is included in the subgrade, it should not be shown in the profile view. For both methods of special borrow placement, ensure that the mass diagram and the grading quantities reflect roadway construction to the bottom of the special borrow.

   b. Unsuitable Material Replacement. If special borrow is recommended to replace unsuitable material, do not consider it as part of the surfacing section. Designate the excavation required to remove unsuitable material below the surfacing subgrade as subexcavation. The subexcavation limits, depth and replacement material (i.e., special borrow) will be shown in a detail. The location and depth of special borrow will be designated as crosshatched areas on the profile and cross sections. The roadway template shown on the cross sections will be at the bottom of the surfacing section. Ensure that the mass diagram and the grading quantities reflect roadway construction to the bottom of the surfacing section; however, do not include special borrow for subexcavation in the grading quantities or mass diagram. In addition, do not include subexcavation material in the grading quantities or mass diagram if disposed outside the roadway template.

Where special borrow is specified, verify the material's availability and cost effectiveness. The required material may not be available in close proximity to the project or may be too costly or difficult to obtain from landowners. If an excessive price for special borrow is anticipated, it may be cost effective to redesign the roadway typical section. Discuss these issues during the Plan-In-Hand meetings with District Construction, Materials and Right-of-Way personnel. The designer should also discuss with District Construction how special borrow will be measured. Special borrow is typically measured in place and no shrink factor is applied. However, district personnel may elect to measure special borrow at the borrow site. A shrinkage factor needs to be applied to the material when it will be measured at the pit.

7. Approach Grading. The approach grading will be paid the same as the mainline grading. Approach fills will utilize 6:1 slopes within the clear zone, regardless of fill height. This does not apply where the approach is shielded with guardrail. See the MDT Detailed Drawings for cut and fill slopes beyond the clear zone. The fill slopes on public approaches will at least match the existing slopes. Compute earthwork quantities for approaches consistent with Figure 5.2F. Figure 5.2G presents the end areas for standard approaches with a 34' (10.6 m) subgrade width. The procedure for using Figure 5.2F is as follows:

   a. Scale the horizontal distance from the intersection of the mainline surfacing inslope and approach subgrade ① to each break in ground line ②, ④, ⑥ and ⑦ and approach grade, clear zone ③ and cut/fill transition point ⑤ and ⑧. This distance is entered in the "STATION" column of the Earthwork Computations Form.

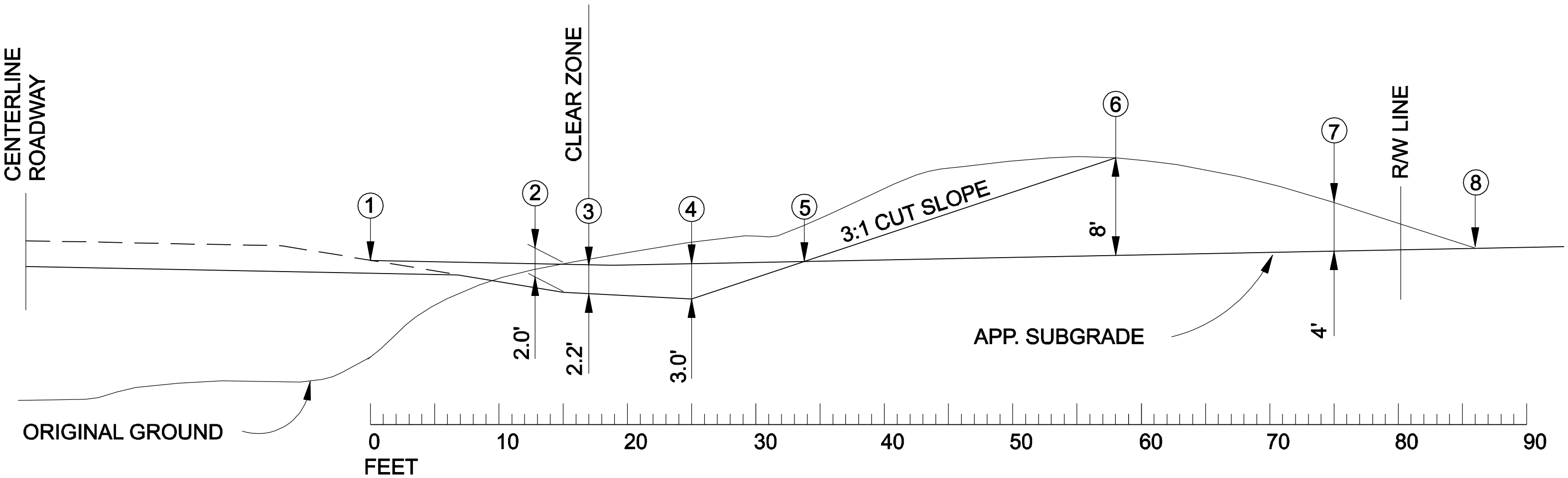
   b. Scale the vertical distance at each point determined in Step #1.

   c. Use the vertical distance to select the area from the appropriate "END AREAS FOR APPROACHES" tables in Figure 5.2G. Enter this area in the "CUT AREA" or "FILL AREA" column of the Earthwork Computations Form.

   d. Complete the Earthwork Computations Form as described in Section 5.2.2.

For approaches involving a significant realignment (e.g., button hook approaches) or change in grade, more detailed earthwork calculations may be necessary. Details that include a plan and profile should be provided for public approaches. For private or farm field approaches, show the horizontal alignment with the appropriate curve radii on the plan sheet. Also provide a profile of the approach on a detail sheet.

8. Slope Flattening Behind Guardrail. Additional embankment material and/or surfacing material is required for slope flattening behind guardrail. See the *MDT Detailed Drawings* for configuration of slope flattening. Use aggregate surfacing material for material placed above subgrade. Depending on the quantity involved, use either embankment or aggregate material for material placed below the subgrade.

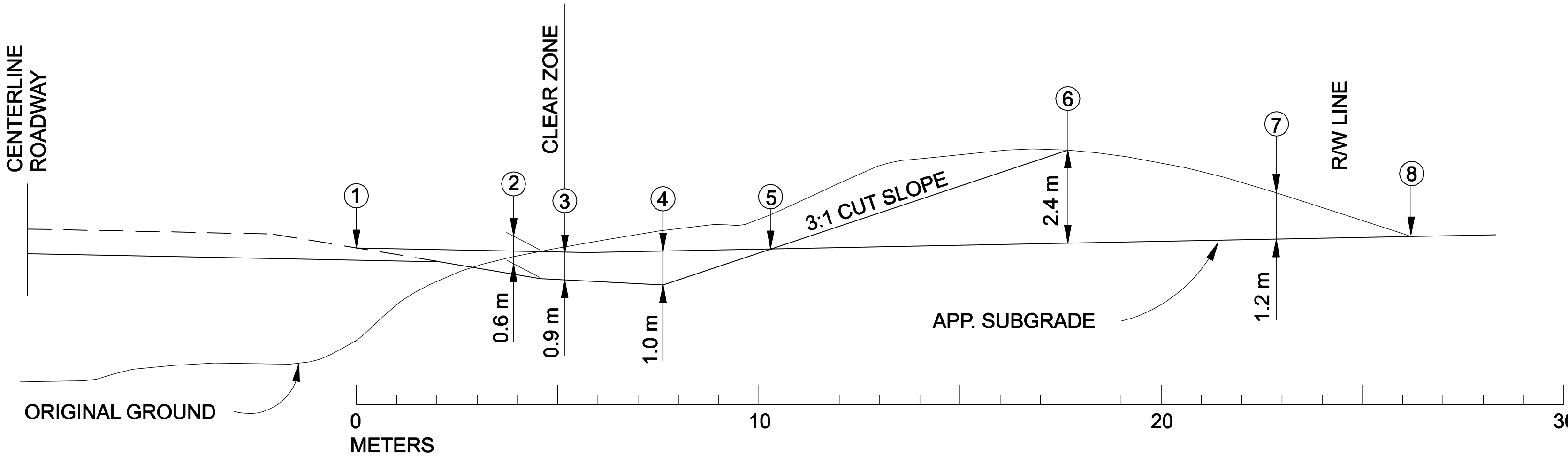


AREA VALUES FROM "END AREAS FOR APPROACHES" TABLES

STATION	DIST. (ft)	AREA IN SQUARE FT: CUT AREA	CUT DOUBLE AREA	FILL AREA	FILL DOUBLE AREA	VOLUME IN CUBIC YARDS: EXCAVATION ACTUAL	SWELL FACTOR	ADJ. EXC.	EMBANKMENT ACTUAL	SHRINK FACTOR	EMB +
1 0+00.00		0		0							
	15		0		77	0			21	35%	29
2 0+15.00		0		77							
	1.8		0		220	0			7		10
3 0+16.8		0		143							
	8.2		0		308	0			47		63
4 0+25.0		0		165							
	8.8		0		165	0			27		36
5 0+33.8		0		0							
	24.2		528		0	237			0		0
6 0+58.0		528		0							
	17.0		825		0	260			0		0
7 0+75.0		297		0							
	11.0		297		0	61			0		0
8 0+86.0		0		0							
				TOTAL		558					138

EARTHWORK FOR APPROACHES

Figure 5.2F (US CUSTOMARY)



AREA VALUES FROM "END AREAS FOR APPROACHES" TABLES

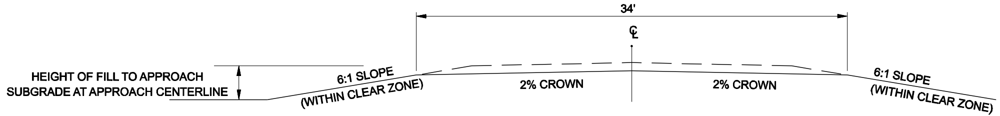
STATION	DIST. (m)	AREA IN SQUARE METERS: CUT AREA	CUT DOUBLE AREA	FILL AREA	FILL DOUBLE AREA	VOLUME IN CUBIC METERS: EXCAVATION ACTUAL	SWELL FACTOR	ADJ. EXC.	EMBANKMENT ACTUAL	SHRINK FACTOR	EMB +
① 0+00.00		0		0							
	4.63		0		7	0			16	35%	22
② 0+04.63		0		7							
	0.55		0		20	0			6		7
③ 0+05.18		0		13							
	2.44		0		28	0			34		46
④ 0+07.62		0		15							
	2.68		0		15	0			20		27
⑤ 0+10.30		0		0							
	7.38		48		0	177			0		0
⑥ 0+17.68		48		0							
	5.18		75		0	194			0		0
⑦ 0+22.86		27		0							
	3.34		27		0	45			0		0
⑧ 0+26.20		0		0							
				TOTAL		416					102

EARTHWORK FOR APPROACHES

Figure 5.2F (METRIC)

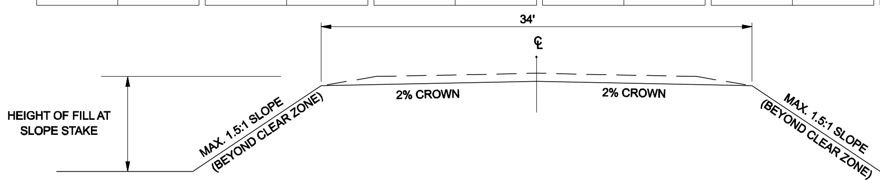
END AREAS FOR APPROACHES - WITHIN THE CLEAR ZONE

6:1 FILL SLOPE		6:1 FILL SLOPE	
HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA
FT	FT^3	FT	FT^3
0.5	11	5.5	341
1.0	31	6.0	390
1.5	53	6.5	443
2.0	79	7.0	498
2.5	107	7.5	557
3.0	139	8.0	618
3.5	173	8.5	683
4.0	211	9.0	750
4.5	251	9.5	821
5.0	295	10.0	894



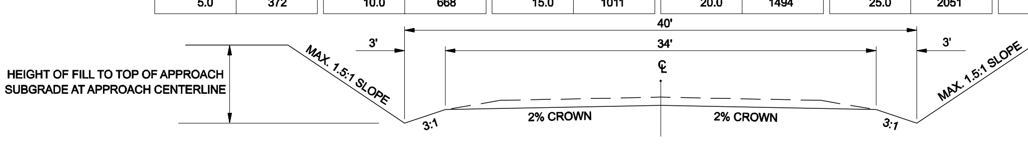
END AREAS FOR FILL APPROACHES - BEYOND THE CLEAR ZONE

4:1 FILL SLOPE		4:1 FILL SLOPE		2:1 FILL SLOPE		2:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE	
HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA
FT	FT^3	FT	FT^3	FT	FT^3	FT	FT^3	FT	FT^3	FT	FT^3
0.5	11	5.5	288	10.5	558	15.5	981	20.5	1301	25.5	1811
1.0	30	6.0	326	11.0	595	16.0	1029	21.0	1348	26.0	1866
1.5	51	6.5	367	11.5	634	16.5	1078	21.5	1397	26.5	1922
2.0	73	7.0	410	12.0	674	17.0	1127	22.0	1446	27.0	1978
2.5	98	7.5	454	12.5	715	17.5	1178	22.5	1496	27.5	2036
3.0	125	8.0	501	13.0	757	1830	1230	23.0	1546	28.0	2094
3.5	153	8.5	550	13.5	800	18.5	1283	23.5	1598	28.5	2153
4.0	184	9.0	600	14.0	843	19.0	1337	24.0	1650	29.0	2212
4.5	216	9.5	653	14.5	888	19.5	1391	24.5	1703	29.5	2273
5.0	251	10.0	707	15.0	934	20.0	1447	25.0	1756	30.0	2334



END AREAS FOR CUT APPROACHES - BEYOND THE CLEAR ZONE

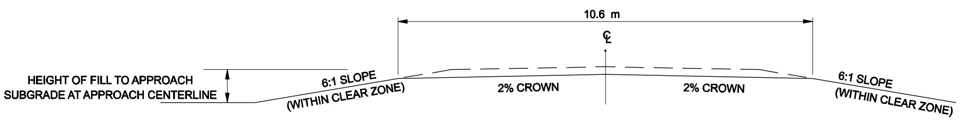
4:1 FILL SLOPE		2:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE	
DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA
FT	FT^3	FT	FT^3	FT	FT^3	FT	FT^3	FT	FT^3	FT	FT^3
0.5	44	5.5	324	10.5	640	15.5	1056	20.5	1546	25.5	2111
1.0	73	6.0	359	11.0	679	16.0	1102	21.0	1599	26.0	2172
1.5	103	6.5	394	11.5	718	16.5	1148	21.5	1653	26.5	2233
2.0	135	7.0	430	12.0	758	17.0	1195	22.0	1708	27.0	2296
2.5	170	7.5	467	12.5	798	17.5	1243	22.5	1763	27.5	2358
3.0	206	8.0	505	13.0	839	1830	1292	23.0	1819	28.0	2422
3.5	245	8.5	544	13.5	881	18.5	1341	23.5	1876	28.5	2486
4.0	285	9.0	585	14.0	924	19.0	1391	24.0	1934	29.0	2552
4.5	327	9.5	626	14.5	967	19.5	1442	24.5	1992	29.5	2617
5.0	372	10.0	668	15.0	1011	20.0	1494	25.0	2051	30.0	2684



APPROACH GRADING QUANTITIES
Figure 5.2G (US CUSTOMARY)

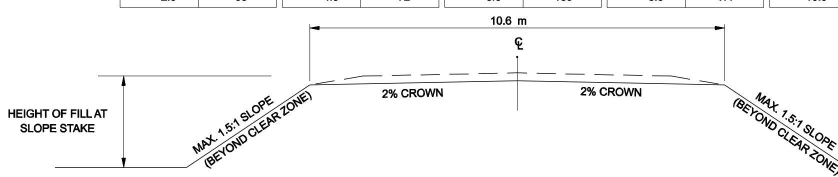
END AREAS FOR APPROACHES - WITHIN THE CLEAR ZONE

6:1 FILL SLOPE		6:1 FILL SLOPE	
HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA
m	m²	m	m²
0.2	2	2.2	49
0.4	4	2.4	56
0.6	7	2.6	64
0.8	11	2.8	73
1.0	15	3.0	81
1.2	19		
1.4	24		
1.6	30		
1.8	36		
2.0	42		



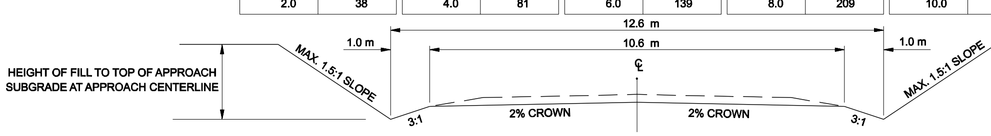
END AREAS FOR FILL APPROACHES - BEYOND THE CLEAR ZONE

4:1 FILL SLOPE		4:1 FILL SLOPE		2:1 FILL SLOPE		1.5:1 FILL SLOPE		1.5:1 FILL SLOPE	
HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA	HEIGHT OF FILL	AREA
m	m²	m	m²	m	m²	m	m²	m	m²
0.2	2	2.2	40	4.2	77	6.2	121	8.2	185
0.4	4	2.4	46	4.4	83	6.4	127	8.4	192
0.6	7	2.6	52	4.6	89	6.6	133	8.6	199
0.8	10	2.8	58	4.8	94	6.8	139	8.8	206
1.0	13	3.0	65	5.0	100	7.0	145	9.0	213
1.2	17	2:1 3.2	53	5.2	106	7.2	151	9.2	221
1.4	21	3.4	57	5.4	113	7.4	158	9.4	229
1.6	25	3.6	62	5.6	119	7.6	164	9.6	236
1.8	30	3.8	67	5.8	126	7.8	171	9.8	244
2.0	35	4.0	72	6.0	133	8.0	177	10.0	252



END AREAS FOR CUT APPROACHES - BEYOND THE CLEAR ZONE

4:1 CUT SLOPE		2:1 CUT SLOPE		1.5:1 CUT SLOPE		1.5:1 CUT SLOPE		1.5:1 CUT SLOPE	
DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA	DEPTH OF CUT	AREA
m	m²	m	m²	m	m²	m	m²	m	m²
0.2	5	2.2	43	4.2	86	6.2	145	8.2	216
0.4	9	2.4	47	4.4	92	6.4	152	8.4	224
0.6	13	2.6	52	4.6	97	6.6	159	8.6	232
0.8	17	2.8	57	4.8	103	6.8	165	8.8	240
1.0	22	3.0	63	5.0	108	7.0	172	9.0	248
1.2	27	1.5:1 3.2	61	5.2	114	7.2	179	9.2	256
1.4	32	3.4	66	5.4	120	7.4	187	9.4	265
2:1 1.6	30	3.6	71	5.6	126	7.6	194	9.6	273
1.8	34	3.8	76	5.8	133	7.8	201	9.8	282
2.0	38	4.0	81	6.0	139	8.0	209	10.0	291



APPROACH GRADING QUANTITIES

Figure 5.2G (METRIC)

EARTHWORK COMPUTATIONS

PROJECT NO. ______________ LOCATION ______________ SHEET ____ OF ____ SHEETS

DESIGNER ______________ DESIGN DATE ______________ CHECK DATE ______________

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS				VOLUME IN CUBIC METERS								
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL −	M

EARTHWORK COMPUTATIONS

PROJECT NO. ______________ LOCATION ______________ SHEET ____ OF ____ SHEETS

DESIGNER ______________ DESIGN DATE ______________ CHECK DATE ______________

GRADES & V.C.	V.C. CORR.	ELEV.	STATION	DIST. (m)	AREA IN SQUARE METERS				VOLUME IN CUBIC METERS								
					CUT		FILL		EXCAVATION			EMBANKMENT			MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	ACTUAL	SWELL FACTOR	ADJ. EXC.	ACTUAL	SHRINK FACTOR	EMB +	CUT +	FILL −	M

5.3 DRAINAGE COMPUTATIONS

Chapter Seventeen presents the criteria for determining quantities for pipes, culverts, culvert ends, bedding material, riprap, irrigation facilities, storm drains and other drainage items. In addition, the designer should note the following:

1. Pipe Sizes. The following will apply:

    a. New. Pipe sizes for new installations are hard converted (e.g., a 914 mm CSP is noted as a 900 mm CSP). See Chapter Seventeen for the applicable US Customary and metric pipe sizes.

    b. Existing. When converting from US Customary to metric dimensions for existing pipe installations, soft convert and round the pipe diameter to the nearest millimeter. For example, a 36” CSP is converted to 914.4 mm and rounded to 914 mm.

       When converting from metric to US Customary dimensions for existing pipe installations it should be noted that metric steel pipe is the actual metric dimension while reinforced concrete pipe is a hard-converted US Customary dimension (i.e. a 900 mm CSP has an inside diameter = 900 mm while a 900 mm RCP has an inside diameter = 914 mm). Consequently, for existing metric CSP, soft convert and round the pipe size to the nearest 0.1”. For example, a 900 mm CSP is converted to 35.43” and rounded to 35.4” and a 900 mm RCP is converted directly to 36”.

2. Rounding. Round pipe lengths up to the nearest 2-foot (0.5 m) increment. Culvert excavation quantities should be rounded in 5 cubic yd (m^3) increments, with a minimum quantity of 5 cubic yd (m^3). Report pipe locations to the nearest whole foot (meter) station.

3. Optional Pipe. On all projects where optional material for mainline culverts is appropriate, specify concrete, steel and aluminum options for each culvert installation, unless otherwise recommended for an individual installation. Plastic options may be included for approach pipes. Where optional pipe material is used, list the approach pipes in a separate summary. Indicate the size and thickness or class of each pipe indicated, including the type of coating required. Irrigation or siphon should be noted, if applicable. Specify the standard corrugation sizes for steel and aluminum pipes and note any exceptions. For each option, compute and report separate quantities for bedding, foundation material, concrete, riprap and geotextile material. Information on culvert size and any special requirements for thickness, class and/or corrugation size will be

furnished by the Hydraulics Section for any culvert larger than 24” (600 mm) on the mainline and 18” (450 mm) on the approaches.

4. End Sections. List the appropriate end section only if a new one is required. If the end section is left in place or relayed, leave the “End Section” column in the Culvert Summary blank.

5. Basic Bid. When concrete is an option, the basic bid culvert is always concrete pipe. Therefore, the size, quantity, length, etc., for the culvert is the same as that for concrete pipe, even though these characteristics may differ for pipe options (e.g., metal pipe). If concrete pipe is not an option, the basic bid item for culvert is the quantity of steel pipe. If only one type of culvert is specified, the basic bid item is the quantity of that particular pipe.

6. Culvert Recap Frame. Summarize the basic bid items of the Culvert Summary Frame in the Culvert Recap Frame and present the total length of each pipe size and the total quantities for bedding material, concrete, foundation material, relay pipe, geotextile, remove pipe and riprap. List irrigation pipe and siphons separately from drainage pipe in the recap. Reference the pipe material, if only one culvert option is specified.

7. Non-Optional Pipe. On projects where optional culvert material is inappropriate (i.e., the type of material is specified), the Culvert Frame (No Option) may be used. Use this frame only if pipe options are not given on the project (e.g., an overlay and widening project where existing culverts are only being lengthened). If both optional and non-optional pipes exist in the project, use the Culvert Frame (Option).

8. Storm Drains. For most projects, the option bid provision will not apply to storm drain installations. Storm drain designs will be prepared by the Hydraulics Section. Except for minor installations, use the Storm Drain Frame to record quantities for storm drain culverts and appurtenant items. Where options are proposed, the Hydraulics Section will provide the recommendations for storm drain installation. Include this information in the summaries and indicate the optional sizes and material types. Where optional materials are specified, determine the basic bid item in the same manner as for culverts.

9. Water Mains. Present water mains in a separate frame from storm drains because they are normally funded separately.

10. Existing Culverts. List the size, length and type of pipe for all culverts to be removed. Designate existing pipe size with the culvert’s true cross-sectional dimensions (e.g., 24” CSP = 610 mm CSP). Culvert removal will be paid by the linear foot (meter) pipe removed regardless of pipe size. Relaying of culverts is

measured and paid per length of culvert. Include the necessary excavation to remove the culvert prior to relaying for information purposes only. Lengthening existing culverts is measured and paid per length of new pipe including associated excavation. See Sections 17.1.11, 17.1.12 and 17.7.1 for criteria on culvert excavation and extension.

11. Culvert Excavation. Culvert excavation is not measured for payment. The quantity of culvert excavation is shown for informational purposes. This work consists of excavation for culvert placement, removal or other installations as shown on the plans. It includes foundation preparation, backfilling and disposal of excavated material. For culvert excavation, use the volume bounded by the bottom elevation of the excavation floor, the vertical planes 1' (0.3 m) outside the inside wall of the pipe, and the vertical planes 1' (0.3 m) beyond the neat line of the end of the pipe or to the width and depth of the bedding/foundation material, whichever is greater. The cost of culvert excavation is included in the unit price bid per linear foot (meter) of new culvert. The cost of excavation for culvert removal, culvert bedding and special foundations is included in the unit prices bid for those items.

12. Trench Excavation. Trench excavation is not measured for payment. The quantity of trench excavation is shown for informational purposes. Trench excavation is typically specified where vertical trench walls are necessary and the trench width is provided. Calculate the quantity of trench excavation in the same manner as described in Item 10 for culvert excavation. However, for the side walls of the trench, use the vertical planes 1.5' (0.5 m) outside the pipe's inside wall or to the width and depth of the bedding/foundation material, whichever is greater. The cost of trench excavation is included in the unit price bid per linear foot (meter) of new culvert. The cost of excavation for culvert bedding and special foundations is included in the unit prices bid for those items

13. Riprap. The Hydraulics Section will specify both the use and dimensions of riprap for permanent erosion control in conjunction with pipe installations. Where excavation is required for riprap placement, the cost of excavation is included in the unit price bid for riprap. For riprap installations at bridges, the specifications, quantities and design data are furnished by the Bridge Bureau.

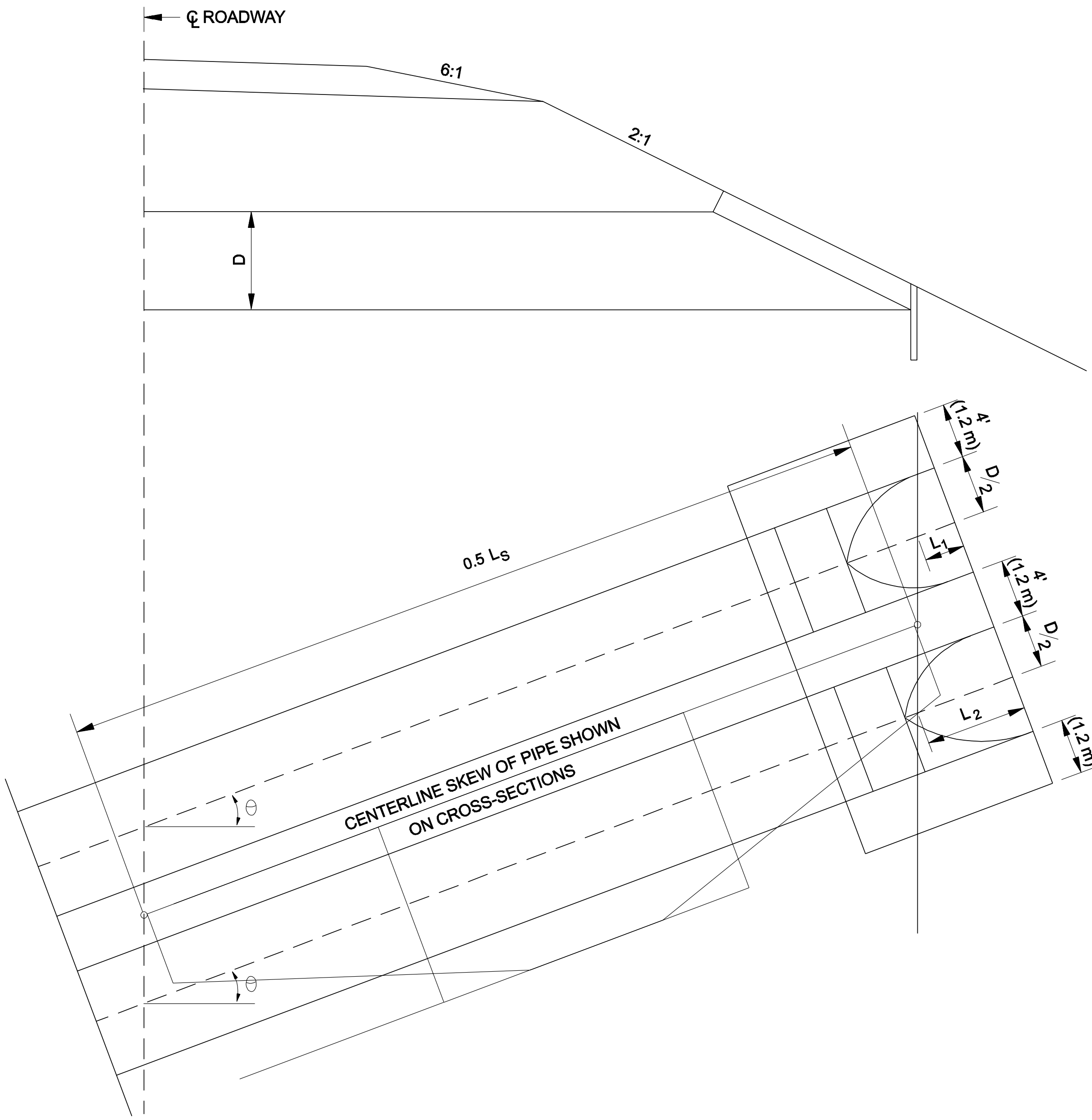
14. Pipe Length. Draw cross drains to scale at the proper flowline on the nearest template cross section. See Chapter Seventeen and the MDT Detailed Drawings for end section criteria and dimensions. If the installation is perpendicular or skewed less than 5°, then the pipe length may be scaled directly from the cross sections. Also consider the following:

a. Do not bid FETS (Flared End Terminal Section) and RACETS (Road Approach Culvert End Treatment Section) separately. Include them in the length of pipe.

b. Where beveled ends are used, measure the pipe length along the pipe flowline.

If the pipe is skewed more than 5°, scale its length along the skewed line (see Section 4.3.11.3).

No additional pipe length is required where skew beveled end sections are provided on a skewed pipe. However, if end sections are perpendicular to the centerline of the skewed pipe, additional pipe length is required; see L_1 and L_2 in Figure 5.3A. Calculate the total pipe length using the following equations:



SKEWED PIPE MEASUREMENTS

Figure 5.3A

a. Single Installation (see Figure 5.3A):

$$L_1 = (D + 2.4)\tan\theta$$

$$L = L_1 + L_S$$

Where:

L	=	total length of pipe, ft (m)
L_S	=	length of pipe measured on skew, ft (m)
L_1	=	additional distance for both ends due to skew, ft (m)
D	=	diameter of pipe, ft (m)
θ	=	angle of skew, degrees

b. Double Installation (see Figure 5.3A):

$$L = (L_1 + L_2) + 2L_S$$

$$(L_1 + L_2) = (4D + 24)\tan\theta$$

Where:

$L_1 + L_2$	=	additional distance for both ends of both pipes due to the skew

15. <u>End Treatments</u>. Quantities for cutoff walls, concrete edge protection and riprap for each pipe size are presented in the MDT Detailed Drawings. Adjust end treatment quantities for skew beveled end sections as follows:

$$T = \frac{Q}{\cos\theta}$$

Where:

T	=	adjusted quantity, cubic yd ($m^{3)}$
Q	=	quantity from MDT Detailed Drawings
$\cos\theta$	=	angle of skew, degrees

5.4 ROADWAY COMPUTATIONS

The Pavement Analysis Section is responsible for determining the type of finished surface, pavement material type and various course thicknesses. The designer is responsible for recording this information on the construction plans and calculating the roadway quantities. Use the criteria and procedures presented in this Section to prepare the typical sections and quantities. The basis for roadway quantities is presented on the Notes Sheet.

5.4.1 Typical Section Geometrics

The following sections present recommended procedures for determining the horizontal dimensions of various surface courses. These horizontal dimensions are used for developing the surfacing quantities and for field construction staking. Surfacing thicknesses are identified on the typical sections in 0.05’ (5 mm) increments. Convert metric dimensions to meters before performing width and quantity calculations.

5.4.1.1 Symmetrical Sections

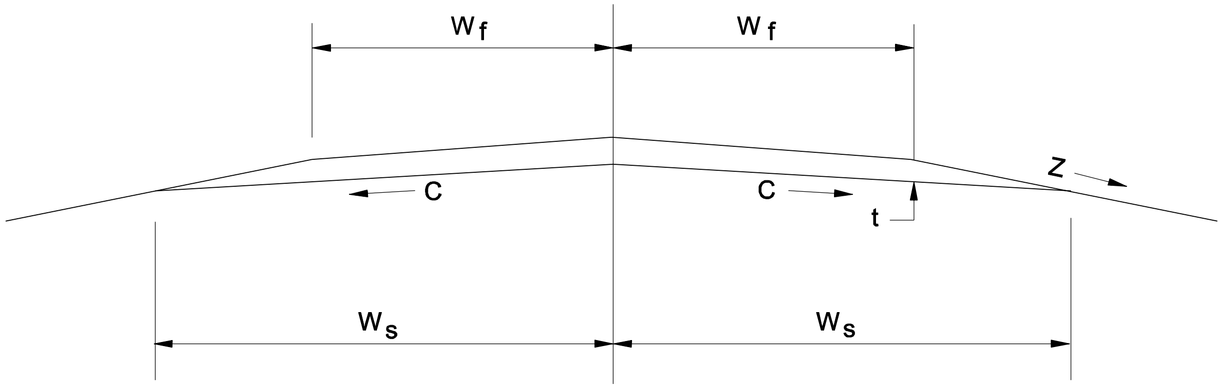
The most commonly used typical section is the 2-lane highway on a tangent alignment with normal cross slopes. In this typical Section, the dimensions of the subgrade width and intermediate surfacing courses are symmetrical about the centerline. The finished roadway width will be determined according to the criteria in Chapter Twelve or as determined during the Preliminary Field Review.

The first step is to establish the width of subgrade using the following equation:

$$W_S = W_f + \left(\frac{tZ}{1-CZ}\right) \qquad \text{(Equation 5.4-1)}$$

where:

W_S	=	half width of subgrade, ft (m)
W_f	=	half width of finished grade, ft (m)
t	=	total surfacing thickness at finished shoulder, ft (m)
Z	=	numerator of side slope ratio (e.g., Z = "6" for a 6:1 side slope)
C	=	crown (e.g., 0.02 for 2% cross slope)



Because of the rounding process, the side slope through the surfacing courses will not be exactly 6:1, but the difference is negligible.

* * * * * * * * * *

<u>Example 5.4-1</u>

	US Customary			Metric		
Given:	W_f	=	20'	W_f	=	6.0 m
	t	=	1.80'	t	=	0.55 m
	Z	=	6:1	Z	=	6:1
	C	=	0.02	C	=	0.02

Problem: Determine width of subgrade.

Solution: Use Equation 5.4-1 and solve for W_s.

US Customary

$$W_S = \frac{(1.8)(6)}{1-(0.02)(6)} + 20$$

$$W_S = 20 + 12.75 = 32.27'$$

$W_S = 32.0$ (Rounded to nearest foot)

Metric

$$W_S = 6.0 + \frac{0.55x6}{1-0.02x6}$$

$$W_S = 6.0 + 3.75 = 9.75\,m$$

$W_S = 9.8\,m$ (Rounded to nearest 0.1 m)

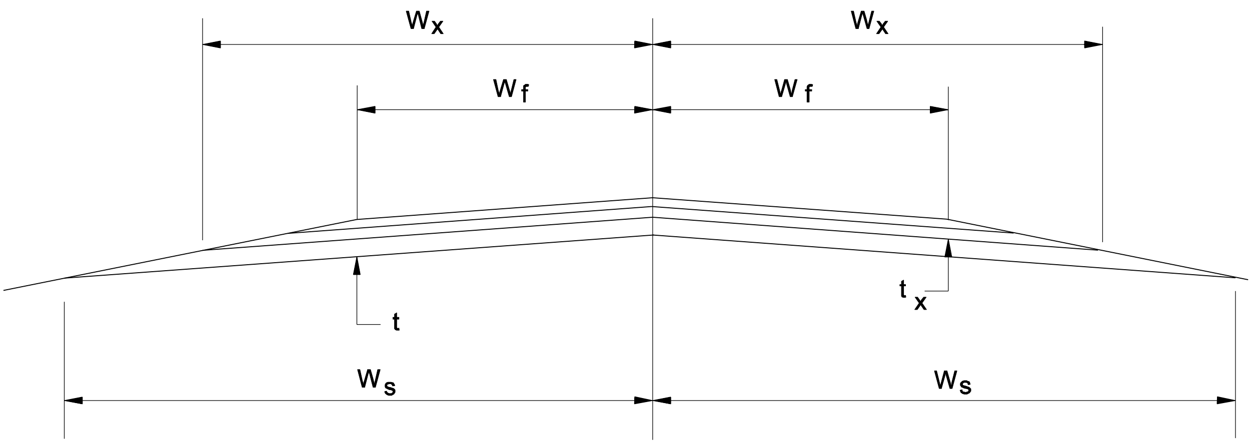
* * * * * * * * * *

The second step is to establish the width of the intermediate surfacing courses. Compute each horizontal course dimension proportionately to its thickness. The width at the top of any surfacing course is determined by the following equation:

$$W_X = W_f + \left[\frac{(W_S - W_f)}{t}\right] t_X \qquad \text{(Equation 5.4-2)}$$

where:

W_X	=	top width of intermediate surfacing course, ft(m)
W_f	=	half width of finished grade, ft(m)
W_S	=	half width of subgrade, ft(m)
t	=	total surfacing thickness at finished shoulder, ft(m)
t_X	=	cumulative thickness of courses above W_X at finished shoulder, ft(m)



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Example 5.4-2 | US Customary | Metric

Given: t_X = 0.80’ | t_X = 0.25 m

Problem: Using the values given in Example 5.4-1, determine the intermediate surfacing course width.

Solution: Use Equation 5.4-2 and solve for W_X

US Customary

$$W_X = 20 + \left[\frac{(32 - 20)}{1.8}\right] 0.80$$

$$W_X = 20 + 5.333 = 25.333'$$

$W_X = 25.3'$ (Rounded to nearest 0.1’)

Metric

$$W_X = 6.0 + \left[\frac{(9.8 - 6.0)}{0.55}\right] 0.25$$

$$W_X = 6.0 + 1.727 = 7.727\ m$$

$W_X = 7.73\ m$ (Rounded to nearest 0.01 m)

* * * * * * * * * *

5.4.1.2 Unsymmetrical Sections

Where sections are not symmetrical about the centerline, compute and record the widths to the left and right of centerline separately. Unsymmetrical sections exist with each superelevated section and with divided highways where inside and outside shoulders have different widths. The widths for unsymmetrical sections are determined as follows:

1. Superelevated Sections. To compute subgrade widths for superelevated sections, use the following equations:

   Low Side

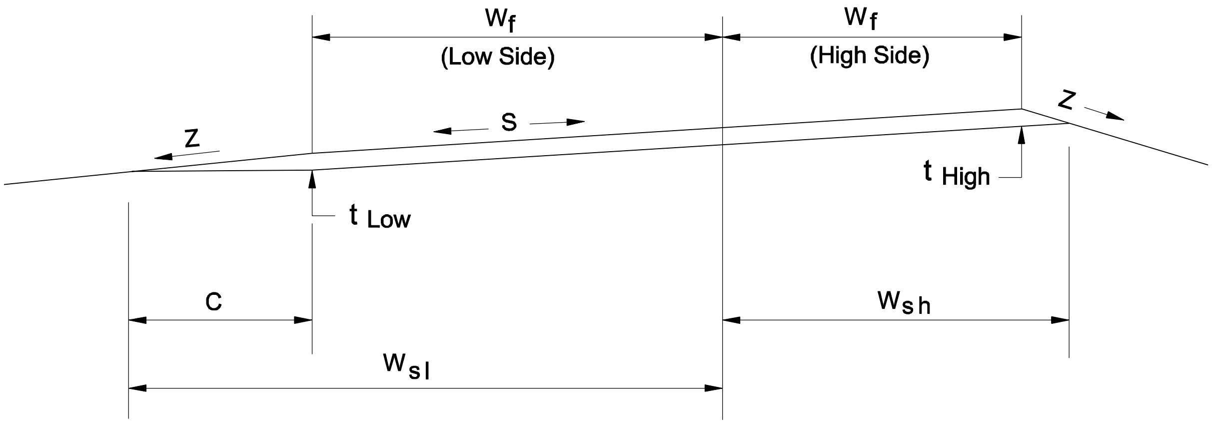
   $$W_{sl} = W_f + \frac{tZ}{1 - CZ} \quad \text{(Equation 5.4-3)}$$

   High Side

   $$W_{sh} = W_f + \frac{tZ}{1 + SZ} \quad \text{(Equation 5.4-4)}$$

   where:

where:	W_{sl}	=	width from centerline to edge of subgrade on low side of superelevation, ft (m)
	W_{sh}	=	width from centerline to edge of subgrade on high side of superelevation, ft (m)
	W_f	=	width of finished grade low or high side, ft (m)
	t	=	total thickness of surfacing at finished shoulder, ft (m)
	S	=	slope of superelevation (%)
	Z	=	numerator of side slope ratio (e.g., Z = "6" for a 6:1 side slope)
	C	=	cross slope of tangent typical



Round each computed value for W_{sl} and W_{sh} to the nearest 1’ (0.1 m).

2. Divided Highways. For both tangent and curve sections of divided highways, compute the subgrade widths left and right of centerline as follows:

Tangent

$$W_S(\text{median}) = W_f(\text{median}) + \frac{tZ}{1-CZ}$$ (Equation 5.4-5)

$$W_S(\text{outside}) = W_f(\text{outside}) + \frac{tZ}{1-CZ}$$ (Equation 5.4-6)

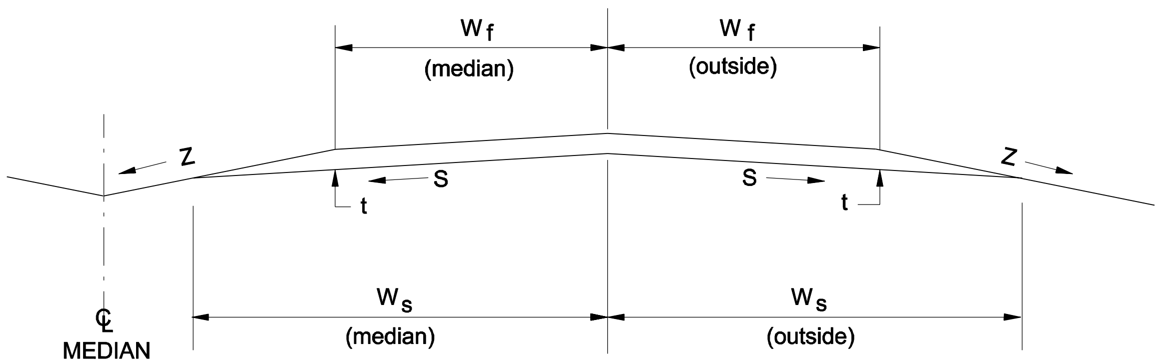
Curve

$$W_S\,(median\ high\ side) = W_f\,(median) + \frac{tZ}{1+SZ}$$ (Equation 5.4-7)

$W_S(\text{outside low side}) =$ same as tangent typical section width

$$W_S(\text{outside high side}) = W_f(\text{outside}) + \frac{tZ}{1+SZ}$$ (Equation 5.4-8)

$W_S(\text{median low side}) =$ same as tangent typical section width



Round the computed W_s (outside) to the nearest 1’ (0.1 m). Where the median is uniformly controlled, round the computed W_s (median) to the nearest 0.1’ (0.01 m). In the case of divided independent roadways, round both W_s (outside) and W_s (median) to the nearest 1’ (0.1 m).

3. Intermediate (High Side). Compute the widths of intermediate surfacing courses for unsymmetrical sections on the high side in the same manner as for symmetrical sections (i.e., proportionately to the thicknesses), except that the width should be computed and recorded separately for each side of the centerline and rounded to the nearest 0.1’ (0.01 m).

4. Intermediate (Low Side). The following example illustrates the procedure that should be used to determine the horizontal distances for the intermediate surface courses on the low side of superelevated curves:

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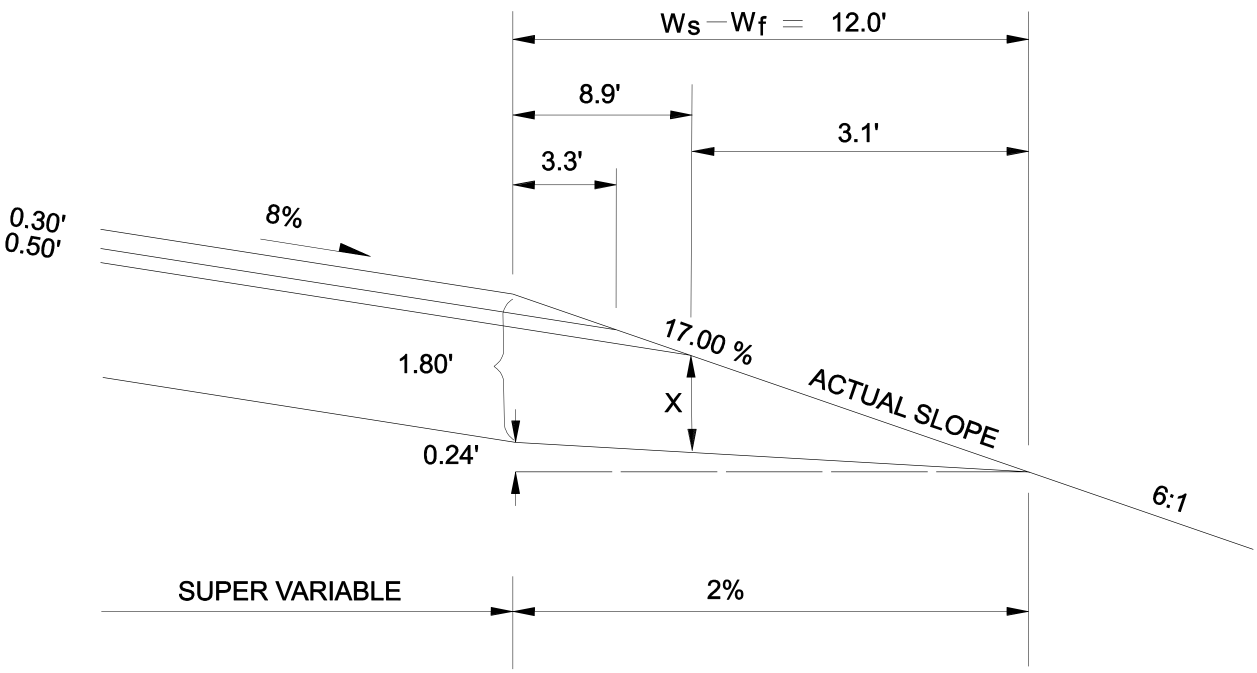
Example 5.4-3 (US Customary)



Given: t = 1.80'

t_{x1} = 0.30'

t_{x2} = 0.50'

W_S = 32.0'

W_f = 20.0'

Superelevation rate = 8%

Subgrade shoulder slope = 2%

Problem: Determine the horizontal distances for the intermediate lifts.

Solution:

1. Determine the actual slope rate.

   Subgrade shoulder width = W_S - W_f = 12.0'
   Rise of subgrade = (12.0) (0.02) = 0.24'
   Total depth = 0.24 + 1.80 = 2.04'
   Actual slope = 2.04 / 12 = 0.1700 or 17.00% (Rounded to the nearest 0.01%)

2. Determine horizontal distance for intermediate lifts.

Slope difference = (17.00 - 8.00)/100 = 0.0900
t_{x1} / slope difference = 0.30 / 0.0900 = 3.33' ~3.3'
(t_{x1} + t_{x2}) / slope difference = 0.80/0.0900 = 8.89' ~ 8.9'

3. Determine "x" for aggregate test (see figure above).

Slope difference = (17.00 – 2.00)/100 = 0.1500
Subbase width = 12 – 8.9 = 3.1'
x = (3.1)(0.1500) = 0.4650'

= 5.6'

Note: "x" must be at least 1.5 times the size of the aggregate. If "x" is less than 1.5 times the size of the aggregate in the first lift, then the first lift is applied parallel to the subgrade (normal crown). Subsequent lifts are applied at the superelevation rate unless "x" is less than 1.5 times the size of the aggregate for a given lift.

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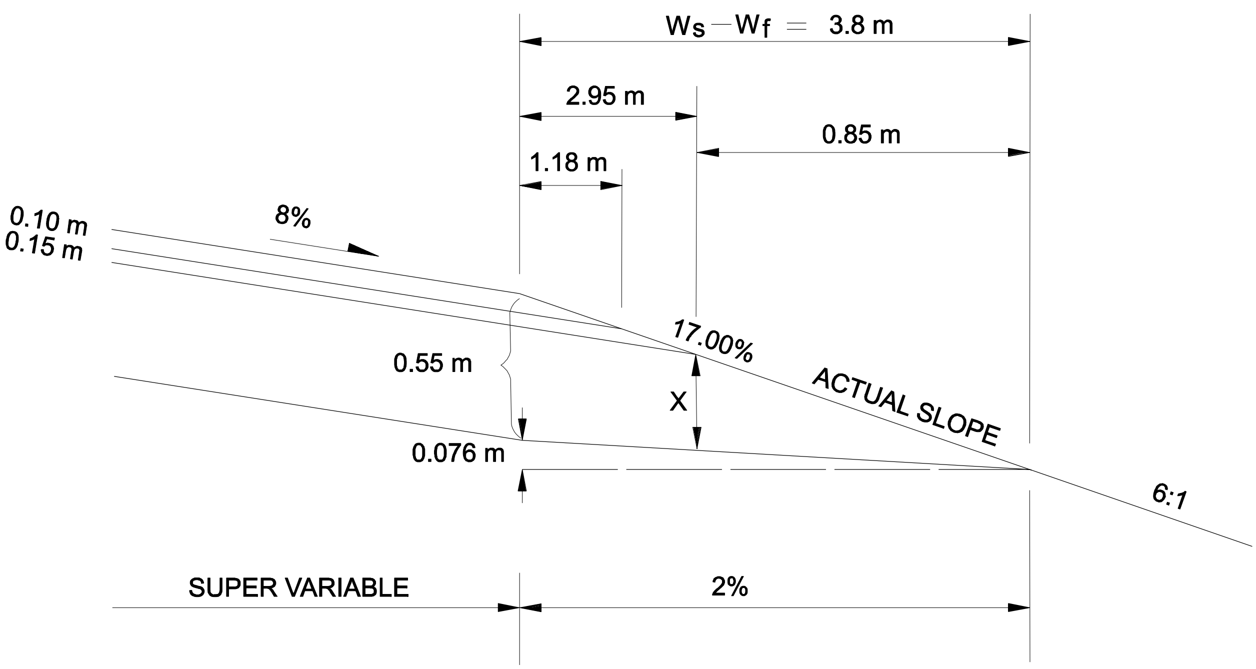
<u>Example 5.4-3</u> (Metric)



Given: t = 0.55 m

t_{x1} = 0.10 m
t_{x2} = 0.15 m
W_S = 9.8 m
W_f = 6.0 m
Superelevation rate = 8%
Subgrade shoulder slope = 2%

Problem: Determine the horizontal distances for the intermediate lifts.

Solution:

4. Determine the actual slope rate.

Subgrade shoulder width = W_S - W_f = 9.8 - 6.0 = 3.8 m
Rise of subgrade = 3.8 m x 0.02 = 0.076 m
Total depth = 0.076 + 0.55 = 0.626 m
Actual slope = 0.626/3.8 = 0.1647 or 16.47% (Rounded to the nearest 0.01%)

5. Determine horizontal distance for intermediate lifts.

Slope difference = 16.47 - 8.00 = 8.47%
t_{x1} / slope difference = 0.10/0.0847 = 1.18 m
(t_{x1} + t_{x2}) / slope difference = 0.25/0.0847 = 2.95 m

6. Determine "x" for aggregate test (see figure above).

Slope difference = 16.47 - 2.00 = 14.47%
Subbase width = 3.8 - 2.95 = 0.85 m
x = 0.85 x 0.1447 = 0.123 m

Note: "x" must be at least 1.5 times the size of the aggregate. If "x" is less than 1.5 times the size of the aggregate in the first lift, then the first lift is applied parallel to the subgrade (normal crown). Subsequent lifts are applied at the superelevation rate unless "x" is less than 1.5 times the size of the aggregate for a given lift.

* * * * * * * * * *

5.4.2 <u>Typical Section Quantities</u>

For each typical section, determine the quantities per station for each type of surfacing material. These quantities will be used to compute the total surfacing quantities for the entire project. Use the procedures in the following sections to determine surfacing quantities and follow the rounding criteria as directed before proceeding to the next step.

5.4.2.1 Typical Sections

Provide a quantities frame for each tangent typical section. Use these frame values to estimate the surfacing quantities for each applicable section. Tangent typical sections are also used to calculate the quantities for superelevated sections that have the same finished top widths and surfacing depths. Use the criteria presented in Section 5.4.1 and Figure 5.4A to round each item in the Quantities Frame.

For widening projects, calculate the gravel quantities as though the existing surfacing is cut on a 3:1 slope from the finished surface to the top of the subgrade at a given distance from the centerline of the roadway. On the typical section, and the cross sections show the dashed slope (3:1±) and label it “Construction Slope.”

US Customary

QUANTITIES									
Units	AGGREGATE			Units	BITUMINOUS MATERIAL			Agg. Treatment	
	Cover	Plant Mix	Crushed Agg. Course**		Asphalt Cement	Seal	Tack	Dust Palliative	Agg. Tack
Area ft²	—	0.01	0.01	yd²/Sta.	—	1	1	1	1
yd³/Sta.	—	0.1	0.1	tons/Sta.	0.01	0.01	—	0.01	—
tons/Sta.	—	0.1	*0.1	Gal/Sta.	—	—	1	—	1
Yds^2/Sta	1	—	—	—	—	—	—	—	—

*The basis of payment for these items are typically paid for at the unit price bid per cubic yard.

Metric

QUANTITIES									
AGGREGATE				BITUMINOUS MATERIAL					
Units	Cover	Plant Mix	Crushed Agg. Course**	Units	Asphalt Cement	Seal	Tack	Dust Palliative	Agg. Tack
m²	—	0.001	0.001	m²/Sta.	—	1	1	1	1
m³/Sta.	—	0.01	0.1	t/Sta.	0.01	0.01	—	0.01	—
t/Sta.	—	0.1	*0.1	L/Sta.	—	—	1	—	1
m²/Sta	1	—	—	—	—	—	—	—	—

*The basis of payment for these items are typically paid for at the unit price bid per cubic meter.

** Crushed base course or crushed top surfacing may be specified for gravel roads.

QUANTITIES FRAME ROUNDING CRITERIA
(Typical Section)

Figure 5.4A

US Customary

QUANTITIES														
AGGREGATE						Units	BITUMINOUS MATERIAL				CEMENT		AGG. TREATMENT	
UNITS	Cover	Plant Mix	Cr. Agg. Course	Cement Treated Base	Blotter		Asphalt Cement	Seal	Tack	Curing Seal	Portland Cement	Fly Ash	Dust Palliative	Agg. Tack
AREA(ft²)	—	0.01	0.01	0.01	0.1	yd²/Sta	—	1	1	1	—	—	1	1
yd³/Sta.	—	0.1	0.1	0.1		Tons/Sta	0.01	0.01	—	0.01	0.1	0.1	0.01	—
Tons/Sta	—	0.1	0.1*	0.1	1	Gal/Sta	—	—	1	—	—	—	—	1
yds^2/Sta	1	—	—	—	—	—	—	—	—	—	—	—	—	—

Metric

QUANTITIES														
AGGREGATE						Units	BITUMINOUS MATERIAL				CEMENT		AGG. TREATMENT	
UNITS	Cover	Plant Mix	Cr. Agg. Course	Cement Treated Base	Blotter		Asphalt Cement	Seal	Tack	Curing Seal	Portland Cement	Fly Ash	Dust Palliative	Agg. Tack
m²	—	0.001	0.001	0.001	0.1	m²	—	1	1	1	—	—	1	1
m³/Sta	—	0.01	0.1	0.1	—	t/Sta	0.01	0.01	—	0.01	0.1	0.1	0.01	—
t/Sta	0.1	0.1	0.1*	0.1	1	L/Sta	—	—	1	—	—	—	—	1
m²/Sta														

* The Basis of payment for these items is typically paid for at the unit price bid per cubic yard (meter).

QUANTITIES FRAME ROUNDING CRITERIA
CEMENT TREATED BASE
(Typical Section)

Figure 5.4A

. The new gravel surfacing will be keyed into the existing surfacing according to the Standard Specifications.

5.4.2.2 Aggregate Quantities

Determine the aggregate quantities in the Quantities Frame for each typical section by using the following guidelines:

US Customary

1. 1. Aggregate Quantities. Use the following steps to determine aggregate quantities:

   a. Compute the cross-sectional end areas for each course. Round and record the computed end areas to the nearest 0.01 ft^2 (0.001 m^2). Use the rounded answer in Step 1b.

   US Customary | Metric

   End Area (ft^2) = average width x thickness | End Area (m^2) = average width x thickness

   b. Compute the cubic yards per station for each course level. Round the answer to the nearest 0.1 yd^3 (0.1 m^3).

   US Customary | Metric

   yd^3/Sta. = [End Area (ft^2) x 100]/ 27 | m^3/Sta. = End Area (m^2) x 100 m

   Use the rounded answer in Step c. only if the aggregate is paid for by the ton. If the aggregate is paid for by the cubic yard, proceed to Step d.

   c. Compute the metric tons per station. Unless otherwise directed, use an aggregate mass density of 3700 lb (cu yd 2200 kg/m^3). Round the answer to the nearest 0.1 t.

   US Customary | Metric

   $$\text{t/Sta.} = \frac{\text{yd}^3\text{/Sta. x 3700 lbs per cy}}{\text{2000 lbs/ton}}$$

   $$\text{t/Sta.} = \text{m}^3\text{/Sta. x 2.2 t/m}^3$$

   d. Record the computed aggregate quantities in the "Crushed Aggregate Course " column of the Quantities Frame using the criteria illustrated in Figure 5.4A.

2. Plant-Mix Aggregate Quantities. Use the following steps to determine plant-mix quantities:

a. Compute the cross-sectional end areas. If the plant-mix course has uniform thickness, use the same procedure as for other aggregate courses. However, if the shoulder cross slopes are steepened, special computations must be made to accommodate the variable thicknesses. Round and record the end areas to the nearest 0.01 ft^2 (0.001 m^2) and use the rounded answer in Step 2b.

b. Compute the cubic yards per station for the plant mix. Round the answer to the nearest 0.1 yd^3 (0.1 m^3) and use the rounded answer in Step 2c.

US Customary	Metric
yd^3/Sta. = End Area (ft^2) x 100 ft/27	m^3/Sta. = End Area (m^2) x 100 m

c. Compute the tons per station. Unless otherwise directed, use a mass density of 3855 lb/yd^3 (2287 kg/m^3). If alternate aggregate types are used in the project, ensure that the appropriate mass density of the aggregate type is used. Round the answer to the nearest 0.1 t.

US Customary	Metric
t/Sta. = yd^3/Sta. x (3855/2000) t/yd^3	t/Sta. = m^3/Sta. x 2.287 t/m^3

d. Record the plant-mix aggregate quantities in the "Plant Mix" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A.

e. The plant mix surfacing type is selected mainly on the quantity of plant mix used on the project. Use the following guidelines to determine the type of plant mix on projects:

US Customary			
Project	Plant Mix Type	Lift Thickness	
Quantity		Min – Max	Recommended
>10,000 t	½” Grade S	0.10 – 0.20’	0.15 – 0.20’
	¾” Grade S	0.15 – 0.30’	0.20 – 0.25’
<10,000 t	Grade D Commercial		
	Grade C, special cases		

Metric			
Project	Plant Mix Type	Lift Thickness	
Quantity		Min – Max	Recommended
>10,000 MT	12.5 mm Grade S	35 – 65 mm	40 – 60 mm
	19 mm Grade S	50 – 90 mm	60 – 75 mm
10,000 MT	Grade D Commercial		
	Grade C, special cases		

Use Grade C (PMS) on projects with very small quantities (e.g., minor work). Grade C (PMS) is usually produced by a commercial plant. For Grade C and Grade D Commercial do not include a separate pay item for asphalt cement, fillers, hydrated lime, additives, dust palliative, aggregate tack, and tack for either mix. However show these quantities for informational proposes only.

f. Reclaimed Asphalt Pavement (RAP). Do not use RAP for any Grade S plant mix. Where RAP will be used, specify a Grade D RAP plant mix in the bottom lift and Grade S in the top lift. Specify a 50% RAP for the lower lifts of hot plant recycle plant-mix surfacing. A 50% RAP mix allows the use of a 30% to 50% range for reclaimed asphalt pavement. A 50% RAP mix is permitted for ramps on Interstate projects. The unit weight of the RAP is equal to the unit weight of new plant mix (3855 lb/cu yd or 2287 kg/m^3).

3. Grade S Plant Mix (Superpave). Grade S plant mix is a unique aggregate mixture that is designed for the available aggregate on each project. It is not based on gradations, but is tested for compliance with specified properties. Reclaimed Asphalt Pavement (RAP) cannot be used for Grade S plant mix.

4. Aggregate Cover Material. For seal coat operations calculate the square yards (square meters) per station and round to the nearest 1 square yard (1 square meter). Record this value in the "Cover" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A.

5. Blotter. Where the cement-treated base will carry traffic during construction, use blotter material to cover the curing seal at a rate of 1.7 lbs/ft^2 (8.2 kg/m^2). To determine the quantity of blotter needed calculate the area of the CTB surface in square feet. Do not apply blotter to aggregate tack.

6. Cement-Treated Surfacing. Use the following guidelines to estimate cement-treated surfacing quantities:

   Cement-Treated Base Aggregate. Cement is added to the Cement-Treated Base (CTB) to increase the structural strength of the surfacing. The greater strength allows the use of thinner aggregate sections. Cement-Treated Base typically extends 1.0’ (0.3 m) beyond the outside edges of the travel lanes and then on a 1:1 slope to the top of the subgrade. Estimate the cubic yards (meters) of Cement Treated Base using the average of its top and bottom width times the depth and record the computed area in the “CEMENT TREATED BASE” column of the Quantities Frame. Unless otherwise directed use an aggregate mass density of 3620 lbs per cubic yard (2148 kg per cubic meter) for CTB. Record the computed quantities in the “CEMENT TREATED BASE AGGREGATE” column of the Quantities Frame using the same rounding criteria shown in Figure 5.4A for Crushed Aggregate Course. Estimate the quantity of the cement using 5% of the computed mass of the CTB and record this amount in the “Cement” column of the Quantities Frame using the same rounding criteria shown in Figure 5.4A for Asphalt Cement. The cement is added to the CTB during the pug-milling of the aggregate.

   Cement-Treated Pulverized Base. A cement-treated pulverized base also increases the strength of the surfacing. The existing paved surface is pulverized and mixed with the existing base aggregate prior to application of the cement. The cement is added and mixed into the pulverized surface. Estimate the square meters of Cement-Treated Pulverized Base and record the total in the “CEMENT TREATED PULVERIZED BASE” column of the Quantities Frame. The depth of pulverization and the percentage of cement will be provided by the Materials Bureau. The quantity of cement will be calculated using the specified percentage and a mass density of 3620 lbs per cubic yard (2148 kg per cubic meter) for the entire pulverized section. A different mass density will not be used for the pulverized plant mix. Record the computed quantity in the “CEMENT” column of the Quantities Frame.

   The Surfacing Design Section will determine the need for cement-treated and cement-stabilized bases. However, a CTB alternate should be evaluated whenever the depth of the crushed aggregate course exceeds 1.30’ (400 mm).

5.4.2.3 Bituminous Material Quantities

For estimating purposes, assume the bituminous material has a mass density of 8.5 lbs/gal (1.02 kg/L). Use the following guidelines to determine the bituminous material quantities in the Quantities Frame for each typical section:

1. Performance Graded Asphalt Cement. All grades of asphalt cement will be referred to as Performance Graded Asphalt Binders (PGAB). The PGAB will be followed by two numbers (e.g., PG 64-28). The first number is an indicator of rut resistance and the second number is an indicator of its resistance to thermal cracking at temperature extremes.

   Separate columns should be provided where more than one PGAB is used on a project.

   Where Grade S aggregate is used, estimate the quantity of asphalt cement at 5.4% for ¾” (19mm) and 5.8% for ½” (12.5mm) of the computed mass of the plant mix and round to the nearest 0.01 t/Sta. For all other aggregates and each grade of asphalt cement, including PGAB, estimate the quantity at 6.0% of the computed mass of the plant mix and round to the nearest 0.01 t/Sta. Record this value in the bituminous material "Asphalt Cement" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A

   Where Recycled Asphalt Pavement (RAP) is used, the quantity of asphalt cement is based on the percentage of RAP used in the surfacing.

   a. For 10% RAP, estimate the quantity of asphalt cement at 5.0% of the computed mass of the plant mix.

   b. For 25% RAP, estimate the quantity of asphalt cement at 4.5% of the computed mass of the plant mix.

   c. For 40% RAP, estimate the quantity of asphalt cement at 3.6% of the computed mass of the plant mix.

   d. For 50% RAP, estimate the quantity of asphalt cement at 3.0% of the computed mass of the plant mix.

   Record this value in the bituminous material “Asphalt Cement” column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A.

2. Dust Pallative. Estimate dust palliative at an application rate of 0.3 gal/sq yd (1.4 L/m^2) of surface area of the top aggregate course. For computational purposes, also convert this value to (metric) tons per station assuming a unit weight an of 10.8 lbs/gal (1.3 kg/L). Record both the surface area and tons per station in the

bituminous material "Dust Palliative" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A

3. <u>Tack Oil & Aggregate Tack Oil</u>. Estimate tack oil at a rate of 0.025 gal/sq yd (0.12 L/m^2) between the lifts of plant-mix material and between the plant-mix surfacing and the bituminous-stabilized base courses. Tack oil may also be applied between CTB and the plant mix surface. Although not accurate, it is acceptable to use the area at the bottom of the plant mix to estimate tack oil quantities. Record the quantities in the bituminous material "Tack" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A. Tack oil quantities are presented in gallons (liters).

   Apply aggregate tack at a rate of 0.05 gal/sq yd (0.23 L/m^2) between the crushed aggregate course and the first lift of plant mix. When a plant mix overlay is placed on top of PCCP apply aggregate tack on top of PCCP at a rate of 0.05 gal/sq yd (0.23 L/m^2). Record the quantities in the bituminous material "Aggregate Tack" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A. Tack oil quantities are presented in gallons (liters).

4. <u>Fog Seal</u>. Discuss the need to apply a fog seal to the finished surface of the plant-mix surfacing at the Plan-In-Hand meeting. If applied, estimate fog seal quantities at a rate of 0.01 gal/yd^2 (0.06 L/m^2) of surface area of the plant-mix finished surface. Record the quantities in the bituminous material “FOG SEAL” column of the Quantities Frame using the rounding criteria for tack illustrated in Figure 5.4A. On the project estimate, include the fog seal quantity in the total quantity for tack.

5. <u>Seal Oil</u>. Estimate seal oil at a rate of 0.40 gal/yd^2 (1.8 L/m^2) of surface area of the plant-mix finished surface or the surface area of the top aggregate course where a double bituminous surface treatment is applied. For computational purposes, also convert this value to tons per station assuming an application rate of 0.0017 tons/yd^2 (for metric tons the conversion is 0.001 836 t/m2). Record both the surface area and the number of tons per station in the bituminous material "SEAL" column of the Quantities Frame using the rounding criteria illustrated in Figure 5.4A. Seal and cover is typically applied to mainline travel lanes and shoulders only. Discuss the need to apply seal and cover to approaches, turnouts, etc., during the Plan-In-Hand. Typically, the Department uses cover material Grade 2A (Type II) or Grade 4A (Type I) with CRS-2P Seal.

6. <u>Double Bituminous Surface Treatment</u>. Use the following application rates to estimate double bituminous surface treatment quantities:

   a. Aggregate (first application) — 27.8 lb/yd^2 – ¾” stone (16.25 kg/m^2 -19 mm stone)

b. Aggregate (second application) — 22.8 lbs/yd^2 – ½" stone (13.55 kg/m^2 - 13 mm stone)
c. Bituminous material (first application) — 0.41 gal/yd^2 (2.05 L/m^2)
d. Bituminous material (second application) — 0.36 gal/yd^2 (1.80 L/m$^{2)}$

7. Curing Seal. Use the following guidelines to estimate the curing seal for Cement-Treated Surfacing:

   A curing seal is typically placed on top of the CTB. Estimate curing seal at the application rate of 0.2 gal/yd^2 (0.9 L/m^2). CRS-2 oil is typically used for the curing seal. Record both the surface area and the number of tons per station in the "CURING SEAL" column of the Quantities Frame. Use the above estimating values unless otherwise specified by the Materials Bureau. Curing seal is applied to the top of the Cement-Treated Pulverized Base at the same rate as it is applied to CTB.

5.4.2.4 Portland Cement Concrete Pavement (PCCP)

Quantities

PCCP is measured by the square meter and rounded to the nearest 0.1 sq yd (0.1 m^2). Fillets for widened sections or at drainage structures and similar locations placed monolithic with the pavement are measured as pavement. Areas constructed other than as pavement are deducted from the pavement area (e.g. gutter pan). Do not make any deductions for any fixtures located within the pavement limits that have a surface area of 1.0 sq yd (0.8 m^2) or less.

Where PCCP is specified, include the necessary details in the plans for the various types of joints and joint locations or patterns. See Section on joint details.

PCCP Types

The following are the two basic categories of PCCP:

1. Plain Jointed Pavement. This PCCP has transverse joints without dowel bars. Load transfer across the joint is developed by aggregate interlock. Aggregate interlock relies on the interaction between aggregate particles at the irregular crack face that forms below the saw cut. The Department does not recommend the use of plain jointed pavement for new construction.

   Applications for plain jointed PCCP are where:

   a. truck traffic volumes are less than 80 trucks per day per lane, and

b. slab lengths are shorter than or equal to 15’ (4.5 m).

Figure 5.4B provides the suggested joint spacings for plain jointed pavements based on various thicknesses.

US Customary

Pavement Thickness	Maximum Joint Spacing
5” 6” 7” ≥ 8”	10’ – 12.5’ 12’ – 15’ 14’ – 15’ 15’

Metric

Pavement Thickness	Maximum Joint Spacing
125 mm 150 mm 175 mm ≥200 mm	3.0 m - 3.8 m 3.7 m - 4.5 m 4.3 m - 4.5 m 4.5 m

JOINT SPACING FOR PLAIN JOINTED PAVEMENT

Figure 5.4B

For highway applications, use skewed randomly spaced joints to reduce harmonic induced ride quality problems caused by faulting. The random spacing should be specified at 12’, 15’, 14’, 13’ (3.6 m, 4.5 m, 4.3 m, 4.0 m) and repeated. The skew should be 10º skewed counterclockwise to the direction of traffic movement.

2. Reinforced Jointed Pavement. This PCCP has transverse joints with dowel bars. Dowel bars are round, smooth steel bars placed across transverse joints to transfer loads without restricting horizontal joint movement due to thermal and moisture contractions and expansions. Dowel bars also keep slabs in horizontal and vertical alignment and reduce deflections and stresses due to traffic loads.

   Applications for reinforced jointed PCCP are where:

   a. required slab thickness is 6” (150 mm) or greater,
   b. truck traffic volumes are greater than 80 trucks per day per lane, and
   c. slab lengths are longer than 20’ (6.0 m).

For reinforced jointed pavements, maximum joint spacing is 30' (9.0 m).

Dowel sizes for reinforced jointed pavements and construction joints are shown in Figure 5.4C.

Slab Depth (inches)	Dowel Diameter	Dowel Embedment (inches)	Total Dowel Length (inches)
6	3/4"	5"	14"
6.5	7/8"	5"	14"
7	1"	6"	16"
7.5	1 1/8"	7"	16"
≥ 8"	1 1/4"	8"	17"

Slab Depth (mm)	Dowel Diameter (mm)	Dowel Embedment (mm)	Total Dowel Length (mm)
150	20	125	360
165	22	125	360
180	25	150	400
190	28	180	400
200	32	200	430

Notes:

1. *All dowels are spaced at 12" (300 mm) centers.*
2. *Embedment is on each side of the joint.*
3. *Total dowel length has allowances for joint openings and minor errors in placement.*
4. *On transverse joints, dowels are placed parallel to the profile grade and parallel to the direction of travel.*

DOWEL SIZES FOR REINFORCED JOINTED PAVEMENTS

Figure 5.4C

Joint Details

There are four general classifications of joints for PCCP. Joint types and their functions are discussed below:

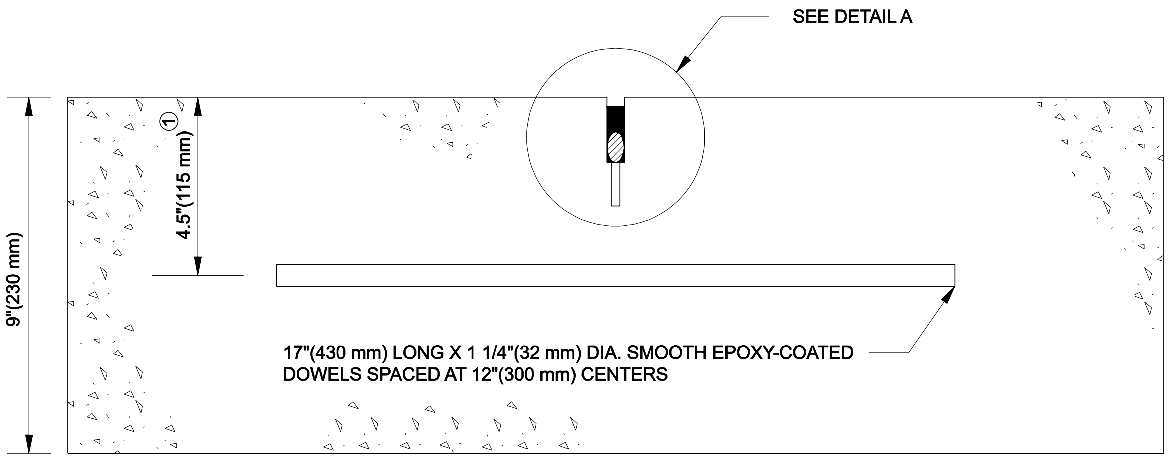
1. Transverse Joints. Transverse joints are placed perpendicular to the roadway's centerline. These joints primarily control the natural transverse cracking due to contraction in the PCCP. Proper transverse joint design for both plain and reinforced pavements will specify the joint interval that will control cracks and provide adequate load transfer across joints.

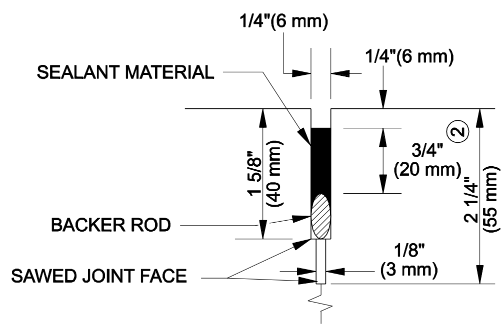
   Joint formation as shown in Figure 5.4D is achieved with an initial saw cut to a depth of at least 25% of the slab thickness and having a minimum width of 1/8" (3 mm). For pavements on stabilized subbases (plant mix base, cement-treated base), the initial saw cut depth should be increased to 33% of the slab thickness. See the manufacturer's specifications for sealant reservoir dimensions. Figure 5.4D also shows a typical sealant reservoir.

2. Construction Joints. These joints are placed at planned interruptions (e.g., at the end of each day's paving, at intersections, where unplanned interruptions suspend operations for an extended period of time). Wherever practical, install the joints shown in Figure 5.4E at the location of a planned joint. These are butt-type joints that need dowels because there is no aggregate interlock to provide load transfer. Dowel size and spacing are the same as shown in Figure 5.4C. To perform properly, the dowel ends extending through the butt joint must be lubricated before paving is resumed. If an unplanned construction joint occurs in the middle two-thirds of the normal joint interval, use a keyed joint as shown in Figure 5.4E with tiebars instead of dowels.

3. Longitudinal Joints. Longitudinal joints are placed parallel to the roadway's centerline. These joints primarily control longitudinal cracking developed from the combined effects of load and restrained warping after pavements are subjected to traffic. On 2-lane and multilane roadway pavements, a spacing of 10' (3.0 m) to 13' (4.0 m) serves the dual purpose of crack control and lane delineation.

   The longitudinal construction joint shown in Figure 5.4F is used for one lane-at-a-time construction. This includes adjacent lanes, shoulders, and curb and gutters. This joint may or may not be keyed depending on the slab thickness, lateral restraint and traffic volumes. The longitudinal contraction joint shown in Figure 5.4G is used where two or more lanes are paved at a time. With slipform paving 2-, 3- or 4-lane pavements can be placed in one pass. These joints depend on the tiebar to maintain aggregate interlock, structural capacity and serviceability.





DETAIL A

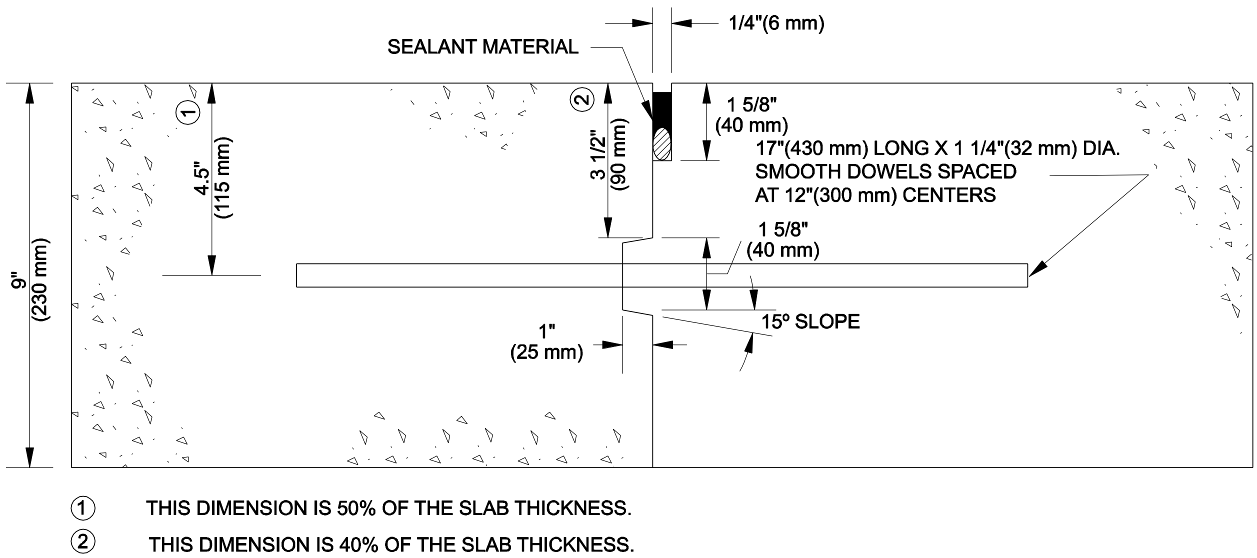
SAWED TRANSVERSE OR LONGITUDINAL
JOINT WITH HOT POURED SEALANT

1 THIS DIMENSION IS 50% OF THE SLAB THICKNESS.

2 THIS DIMENSION IS 25% OF THE SLAB THICKNESS.

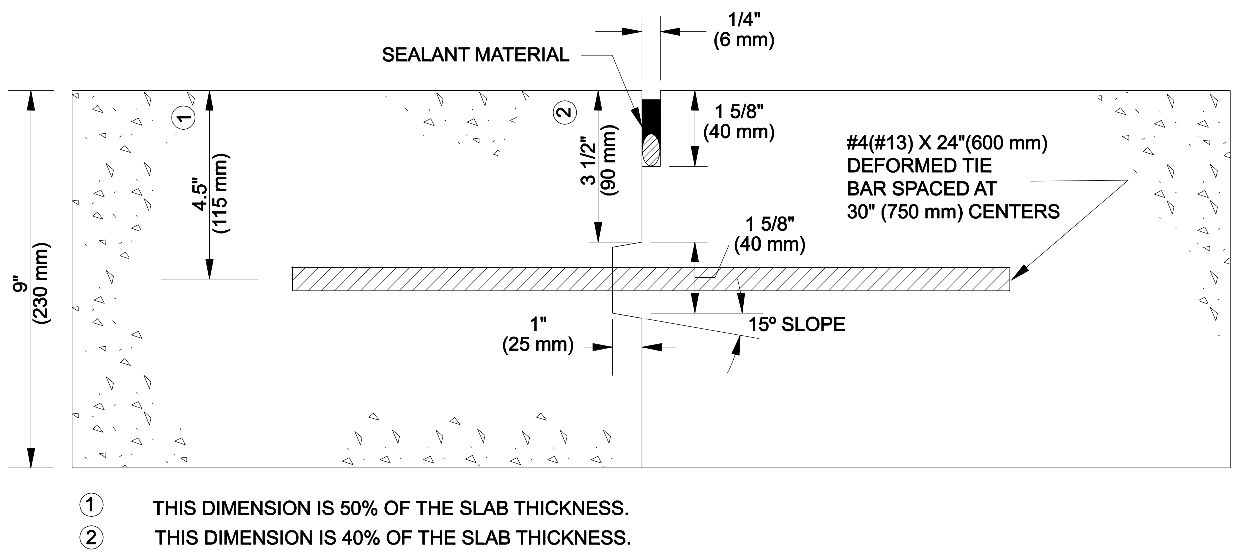
TRANSVERSE CONTRACTION JOINT

Figure 5.4D



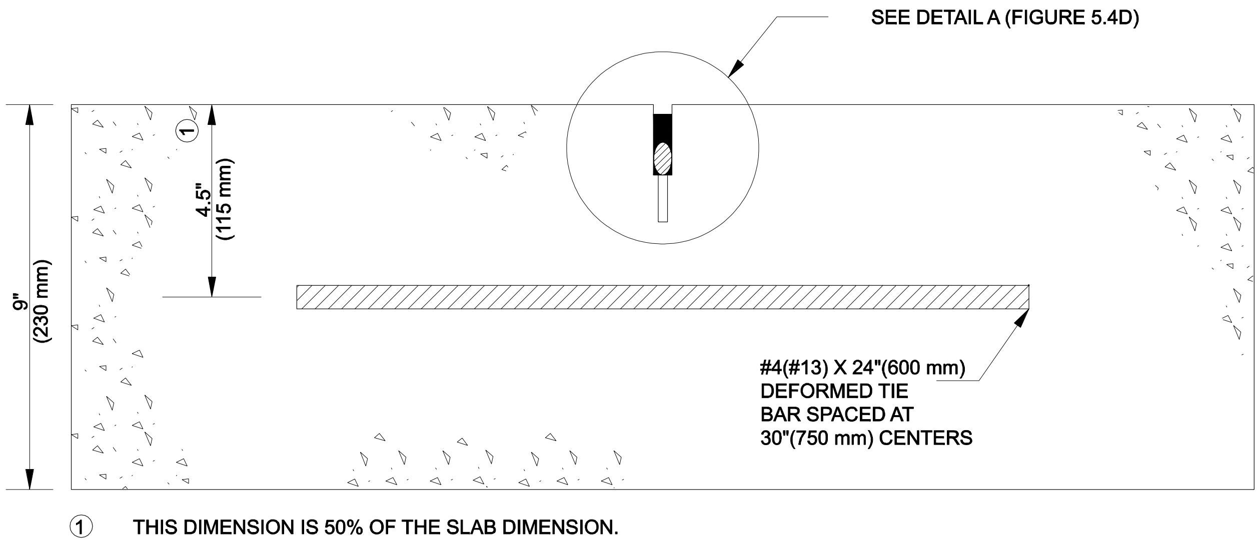
TRANSVERSE CONSTRUCTION JOINT

Figure 5.4E



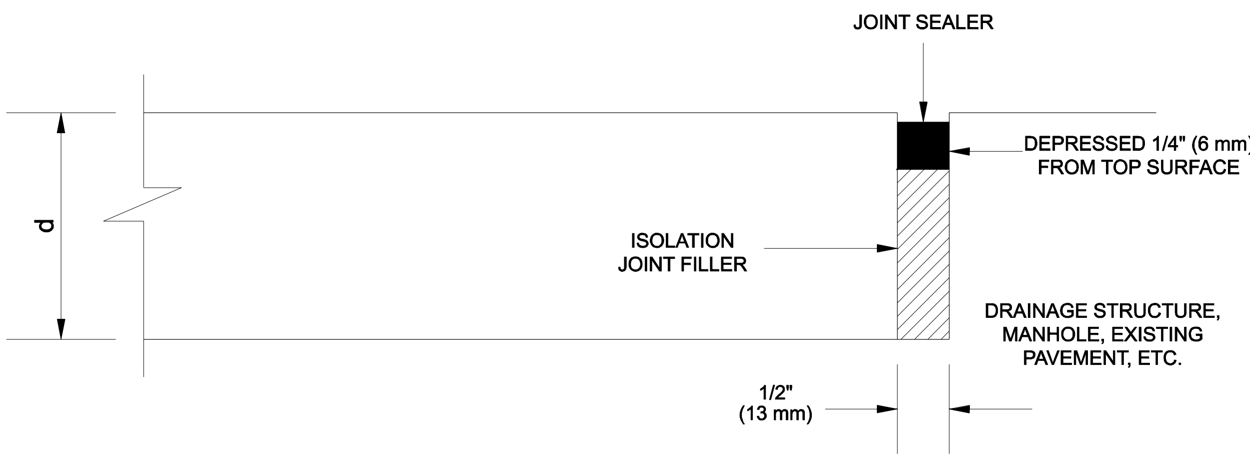
LONGITUDINAL CONSTRUCTION JOINT

Figure 5.4F



LONGITUDINAL CONTRACTION JOINT

Figure 5.4G



NON-DOWELED ISOLATION JOINT

Figure 5.4H

In urban areas, where the pavement is laterally restrained by the backfill behind the curbs, there is no need to tie longitudinal joints with deformed tiebars. However, on roadways not restrained from lateral movement, tiebars must be placed at mid-depth of the slab to prevent the joint from opening due to the contraction of the concrete slabs. Typically, #4 (#13) deformed tiebars by 24” at 30” (600 mm at 750 mm) spacings are used. Do not place tiebars within 15” (380 mm) of transverse joints or they may interfere with the joint movement. Do not coat tiebars with grease, oil or other material that prevents bonding to the concrete.

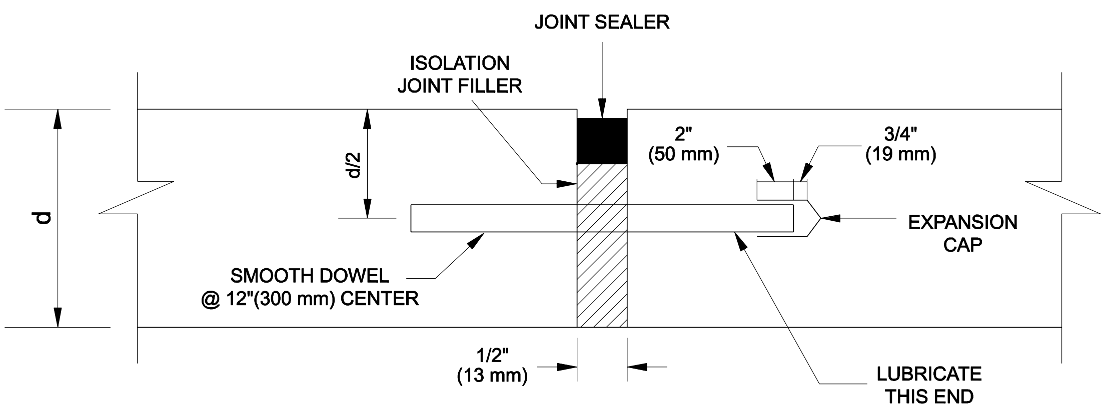
4. Isolation Joints. Isolation joints are placed around in-pavement structures (e.g., drainage inlets, manholes, lighting structures). These joints primarily lessen compressive stresses that develop between the pavement and a structure or between two pavement sections. See Figure 5.4H for a typical isolation joint.

   Isolation joints used at structures (e.g., bridges) should have dowels to provide load transfer and increase pavement performance. See Figure 5.4I for detail of doweled isolation joints.

Jointing Layout

A well designed jointing layout can eliminate unsightly random cracking, can enhance the appearance of the pavement and can provide years of low maintenance service. The following recommendations will help in the design of a proper jointing system.

1. Avoid odd-shaped slabs.
2. Maximum transverse joint spacing for plain jointed pavement should either be 24 or 30 times the slab thickness or 15’ (4.5 m), whichever is less; or 30’ (9.0 m) or less for reinforced jointed pavements.
3. Longitudinal joint spacing should not exceed 12.5’ (3.8 m).
4. Keep slabs as square as practical. Long narrow slabs tend to crack more than square ones.
5. All transverse contraction joints must be continuous through the curb and have a depth equal to 25% to 33% of the pavement thickness depending on the subbase type.
6. In isolation joints, the filler must be full depth and extend through the curb.



DOWELED ISOLATION JOINT

Figure 5.4I

7. If there is no curb, tie longitudinal joints with deformed tiebars.

8. Offsets at radius points should be at least 1.5’ (0.5 m) wide. Avoid joint intersection angles less than 60°.

9. Minor adjustments in joint location made by shifting or skewing to meet inlets and manholes will improve pavement performance.

10. Where the pavement area has drainage structures, place the joints to meet these structure, if practical.

A typical joint layout detail is shown in Figure 5.4J.

5.4.3 Surfacing Quantities (Summary Sheet)

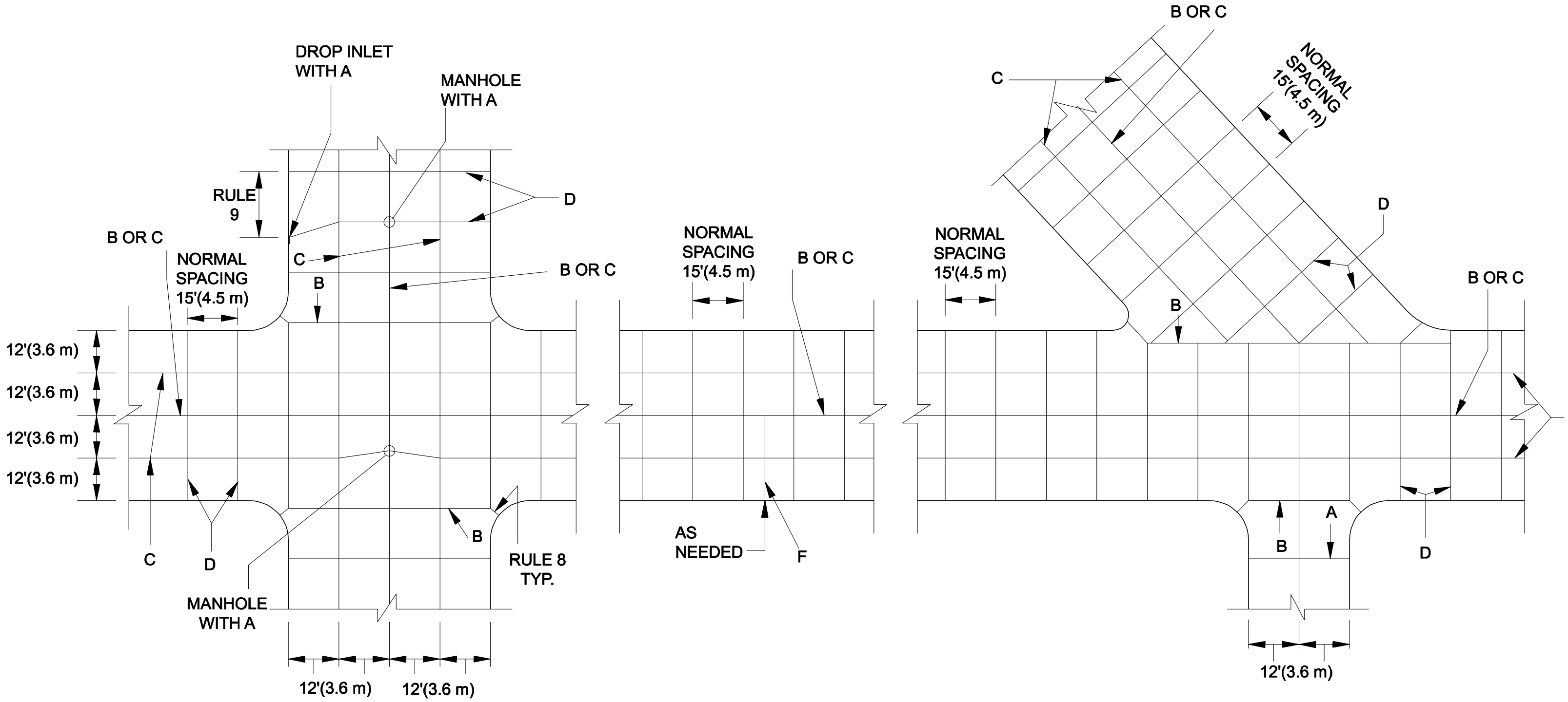
When calculating the quantities for the Surfacing and Additional Surfacing Frame on the Summary Sheets, consider the following guidelines:

1. Typical Section Quantities. For each typical section that has a Surfacing Quantity frame, multiply the quantities by the net number of stations, round the result according to the criteria presented in Figure 5.1A and record the values in the Surfacing Frame. Do not include bridge lengths, as measured from the bridge end bents’ centerline-of-bearing to centerline-of-bearing, in the net length. Provide a separate line in the Surfacing Frame each time the typical section used to calculate quantities changes. Quantities between the transition of two typical sections should also be recorded on a separate line. Estimate transition quantities by multiplying the transition length, in stations (Sta.), by the average quantity of surfacing in the two typical sections.

2. Bridges. Any surfacing of bridges must be approved by the Bridge Bureau. The thickness of plant mix material allowed on bridge decks is based on the structural capacity of the bridge.

3. Hydrated Lime. Typically, hydrated lime is used to treat plant-mix surfacing materials, including RAP. Estimate the quantity of hydrated lime at 1.4% of the mass of plant mix, round to the nearest (metric) ton and record the total in the Surfacing Frame on the Summary Sheets.

4. Additional Surfacing Frame. Use the Additional Surfacing Frame to record the surfacing quantities for approaches, connections to PTW, pavement tapers, etc. The quantity totals from the Additional Surfacing Frame are recorded on the bottom of the Surfacing Frame and added to the Surfacing Frame totals.



A. Isolation joints
B. Longitudinal construction joints
C. Longitudinal contraction joints
D. Transverse contraction joints
E. Planned transverse construction joint
F. Emergency transverse construction joint

PAVEMENT JOINT DETAILS

Figure 5.4J

5. Approach Surfacing Quantities. Chapter Thirteen presents the Department criteria for approaches. Figure 5.4K provides the typical surfacing quantities for approaches. In addition, the designer should consider the following guidelines:

   a. New Construction or Reconstruction Projects. Pave public and private approaches to the right-of-way line. Farm field approaches will be surfaced with gravel to the right-of-way line and will receive a 12’ (3.6 m) plant-mix strip adjacent to the roadway. The decision whether to seal and cover approaches will be determined at the Plan-in-Hand.

   b. Overlay and Overlay/Widening Projects. All public approaches will be overlaid to the right-of-way line. On all paved private approaches and all farm field approaches having a paved width of 12’ (3.6 m), provide a 3’ (1 m) plant-mix strip. This strip serves as a transition and reduces the edge-breaking potential of the new pavement.

   c. High-Volume Approaches. Approaches with high volumes of traffic, particularly truck traffic, may require special designs. The surfacing design and layout should be discussed with the Surfacing Design Section and the Geometric Design Section during the development of the project.

   d. Frame Listing. Total the surfacing required for each type of approach and record each total separately in the Additional Surfacing Frame (i.e., all public approaches = 1 item, all private approaches = 1 item, all farm field approaches = 1 item). Approaches that require a lengthy or different surfacing section also should be recorded separately in the Additional Surfacing Frame.

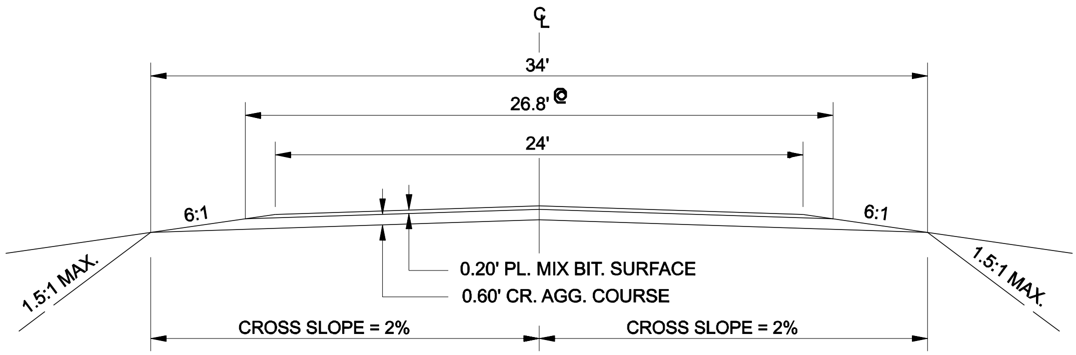
5.4.4 Miscellaneous Roadway Quantities

5.4.4.1 Pavement Markings

The Traffic Engineering Section is responsible for determining both interim and final pavement marking quantities. The designer is responsible for recording each in the Pavement Marking Frame on the Summary Sheet. Round all markings according to the criteria presented in Figure 5.1A.

The designer is responsible for determining the quantities required for temporary pavement markings. Estimate the quantities for each of the following paving operations:

1. each lift of pavement

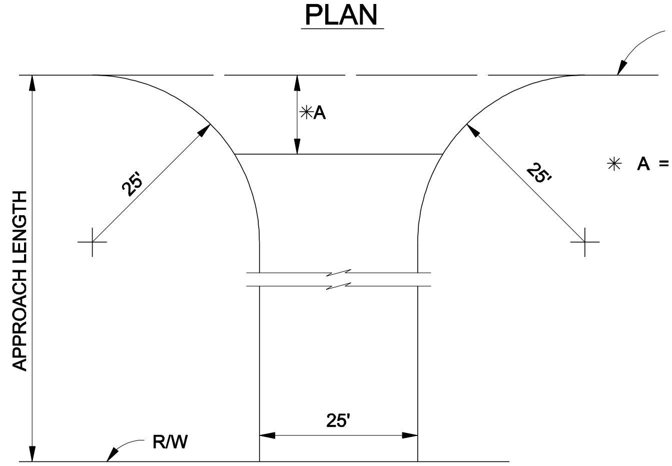


QUANTITIES PER APPROACH (INCL. WYES - 25' RADIUS)							
SURFACING TREATMENT	AGGREGATE		BITUM. MAT'L.			AGGREGATE TREATMENT	
	TONS	yd^3	TONS			TON DUST PALLIATIVE	GALLONS AGGREGATE TACK
	PL.MIX BIT.SURF.	CR. AGG. COURSE	ASPHALT CEMENT				
			6.0%	5.8%	5.4%		
OVERLAY PROJECTS - 3.0' PL.MIX STRIP	2.3		0.14	0.13	0.12		
1ST 25' W/ 12' PL. MIX STRIP	8.1	21.6	0.49	0.47	0.44	0.09	2.9
1ST 25' PL. MIX SURFACED	13.8	21.6	0.83	0.80	0.75	0.18	5.6
EACH ADDITIONAL FOOT	0.4	0.7	0.02	0.02	0.02	0.01	0.2

BASIS OF QUANTITIES

COMP. WT. OF PL. MIX BIT. SURF. = 3855 lbs/yd^3
PL. MIX BIT. MAT'L. = 6.0% OF COMP PLANT MIX BIT. SURF. (GRADE D)
PL. MIX BIT. MAT'L. = 5.8% OF COMP PLANT MIX BIT. SURF. (GRADE S 1/2")
PL. MIX BIT. MAT'L. = 5.4% OF COMP PLANT MIX BIT. SURF. (GRADE S 3/4")
@ DUST PALLIATIVE = 0.3 gal/yd^2 (FOR PUBLIC APP'S ONLY)
@ AGGREGATE TACK = 0.05 gal/yd^2 (FOR PUBLIC APP'S ONLY)

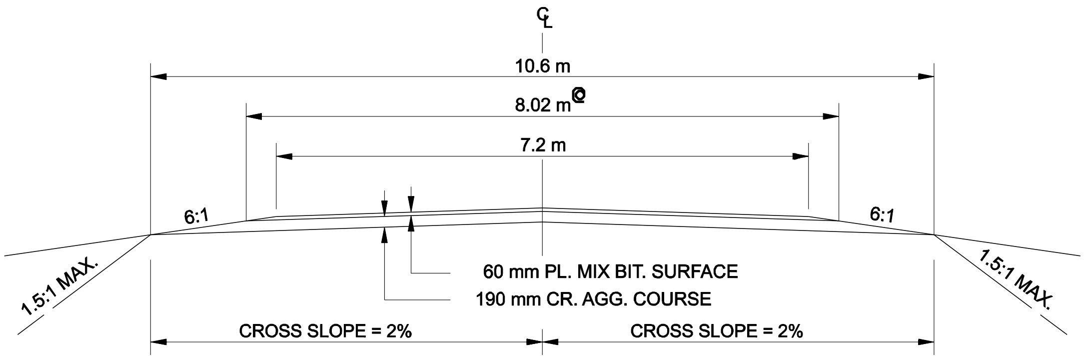
PLAN



✳ A = FARM/FIELD APPROACHES SHOULD BE GRADED AND GRAVELED TO R/W LINE WITH A 12' PLANT MIX STRIP PLACED PARALLEL AND ADJACENT TO ROADWAY. ON OVERLAY PROJECTS A 3' PLANT MIX STRIP SHOULD BE PLACED TO SERVE AS A TRANSITION AND TO REDUCE EDGE OF MATERIAL BREAKOFF.

ESTIMATED QUANTITIES FOR APPROACH SURFACING

Figure 5.4K (US Customary)

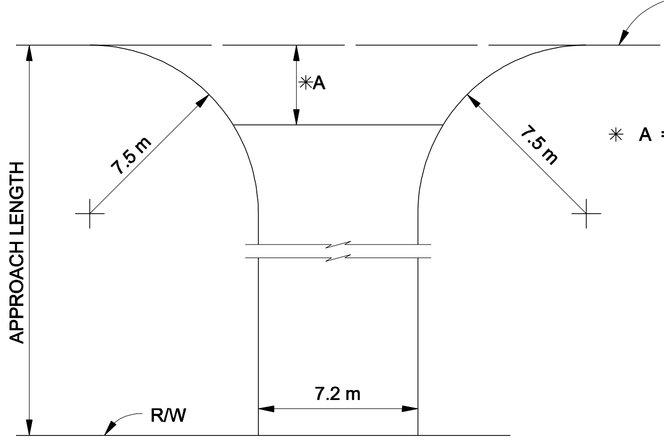


QUANTITIES PER APPROACH (INCL. WYES - 7.5 m RADIUS)							
	AGGREGATE		BITUM. MAT'L.			AGGREGATE TREATMENT	
SURFACING TREATMENT	TONS	m^3	TONS			TON DUST PALLIATIVE	LITERS AGGREGATE TACK
	PL.MIX BIT.SURF.	CR. AGG. COURSE	ASPHALT CEMENT				
			6.0%	5.8%	5.4%		
OVERLAY PROJECTS - 1.0 m PL.MIX STRIP	2.4		0.14	0.14	0.13		
1ST 7.5 m W/ 3.6 m PL. MIX STRIP	6.6	17.1	0.40	0.38	0.36	0.09	11
1ST 7.5 m PL. MIX SURFACED	11.2	17.1	0.67	0.65	0.60	0.15	20
EACH ADDITIONAL METER	1.0	1.8	0.06	0.06	0.05	0.01	2

BASIS OF QUANTITIES

COMP. WT. OF PL. MIX BIT. SURF. = 2287 kg/m^3
PL. MIX BIT. MAT'L. = 6.0% OF COMP PLANT MIX BIT. SURF. (GRADE D)
PL. MIX BIT. MAT'L. = 5.8% OF COMP PLANT MIX BIT. SURF. (GRADE S 1/2")
PL. MIX BIT. MAT'L. = 5.4% OF COMP PLANT MIX BIT. SURF. (GRADE S 3/4")
@ DUST PALLIATIVE = 1.4 L/m^2 (FOR PUBLIC APP'S ONLY)
@ AGGREGATE TACK = 0.23 L/m^2 (FOR PUBLIC APP'S ONLY)

PLAN



✳ A = FARM/FIELD APPROACHES SHOULD BE GRADED AND GRAVELED TO R/W LINE WITH A 3.6 m PLANT MIX STRIP PLACED PARALLEL AND ADJACENT TO ROADWAY. ON OVERLAY PROJECTS A 1 m PLANT MIX STRIP SHOULD BE PLACED TO SERVE AS A TRANSITION AND TO REDUCE EDGE OF MATERIAL BREAKOFF.

ESTIMATED QUANTITIES FOR APPROACH SURFACING

Figure 5.4K (Metric)

Additional quantities of temporary pavement markings may also be required for the existing pavement and for a milled surface. The need for these additional quantities will be determined by District Construction personnel. Compute the quantities for temporary pavement markings for each 2-lane mile (kilometer) of the project and round the result to the nearest 0.1 mile (0.1 km) as illustrated in Figure 5.1A.

5.4.4.2 Guardrail

Chapter Fourteen presents the Department's criteria for guardrail placement. Station limits for guardrail will include the terminal sections and bridge approach sections. Guardrail quantity calculations should reflect the following information:

1. W-Beam Guardrail Quantities. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 12.50' (3.81 m).

2. Cable Guardrail Quantities. Compute the length of need and round up to the next highest multiple post spacing. Post spacing on tangents and curves with radii greater than 720' (220 m) is 16' (4.88 m). Post spacing on curves with a radii less than 720' (220 m) and greater than or equal to 440' (135 m) is 12' (3.66 m). Do not install cable guardrail on the outside of curves with radii less than 440' (135 m) or on the inside of any curve.

3. Box Beam Guardrail Quantities. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 18.0' (5.49 m).

4. Concrete Barrier Rail. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 10' (3.05 m). Concrete barrier rail is paid at the unit price bid for each 10' (3.05 m) increment.

5. Raise Guardrail. Use the pay item "Raise Guardrail" to adjust existing rail to provide 21.625"±3" (550 mm ±75 mm) of distance from the center of the rail to the top of the pavement. Compute and round the quantity up to the nearest 12.5' (3.81 m).

6. Remove Guardrail. Compute and round the quantity up to the nearest 12.5' (3.81 m).

7. Reset Guardrail. Reset Guardrail is not a separate pay item. Provide a quantity of remove guardrail and a quantity of new guardrail for this item of work. Compute and round these quantities up to the nearest 12.5' (3.81 m). The contractor is allowed to use any approved salvaged materials in new installations.

8. Bridge Approaches. Bridge approach sections are included in the station limits but are bid as a separate unit and, therefore, are not included in the length of rail. Ensure the type of bridge approach section specified matches the bridge rail. See the *MDT Detailed Drawings* for the application of each type of bridge approach section. Box beam guardrail can only be connected to Wyoming Bridge Rail. Designer must contact Bridge Bureau.

9. Terminal Sections:

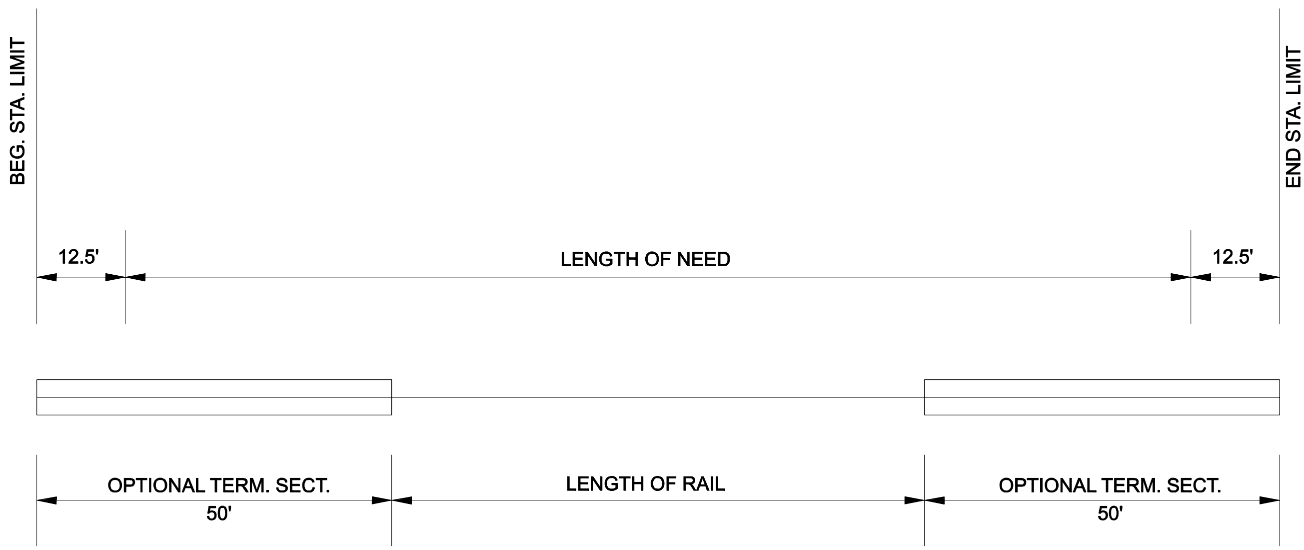
   a. W-Beam Guardrail. The optional terminal section and one-way departure terminal section are included in the station limits but are separate bid items; therefore, it is not included in the length of rail. See Figure 5.4L for computing guardrail lengths with Optional Terminal Sections.

   b. Cable Guardrail. Note that an additional 42’ (12.80 m) of cable guardrail is required on each end beyond the length of need. This additional 42’ (12.80 m) terminal section is measured separately for bidding purposes. Also, note that the maximum run of cable guardrail is 2000’ (609.4 m); see the *MDT Detailed Drawings*. Therefore, with a long run of cable guardrail, there may be several terminal sections. See Figure 5.4M for computing length of cable guardrail.

   c. Box Beam Guardrail. The WY-BET terminal section and terminal section 2 are included in the station limits but are separate bid items; therefore, they are not included in the length of rail. See Figure 5.4N for computing length of box beam guardrail.

10. End Anchors. End anchors are not bid separately, but are included in the cost of the terminal section.

11. Intersecting Roadway Terminal Section. For intersecting roadway terminal section (IRT), the length of rail is bid separately from the guardrail. The station limits of the IRT should extend from the guardrail connection to the end of the IRT. Because the IRT is installed on a radius, the station limits do not reflect the length of the IRT rail. See the *MDT Detailed Drawings* for the selection of radii that will result in 12.5’ (3.81 m) increments of rail. See Figure 5.4O for computing guardrail lengths with intersecting roadway terminal sections. Do not use intersecting roadway terminal sections with box beam rail.



Steps:

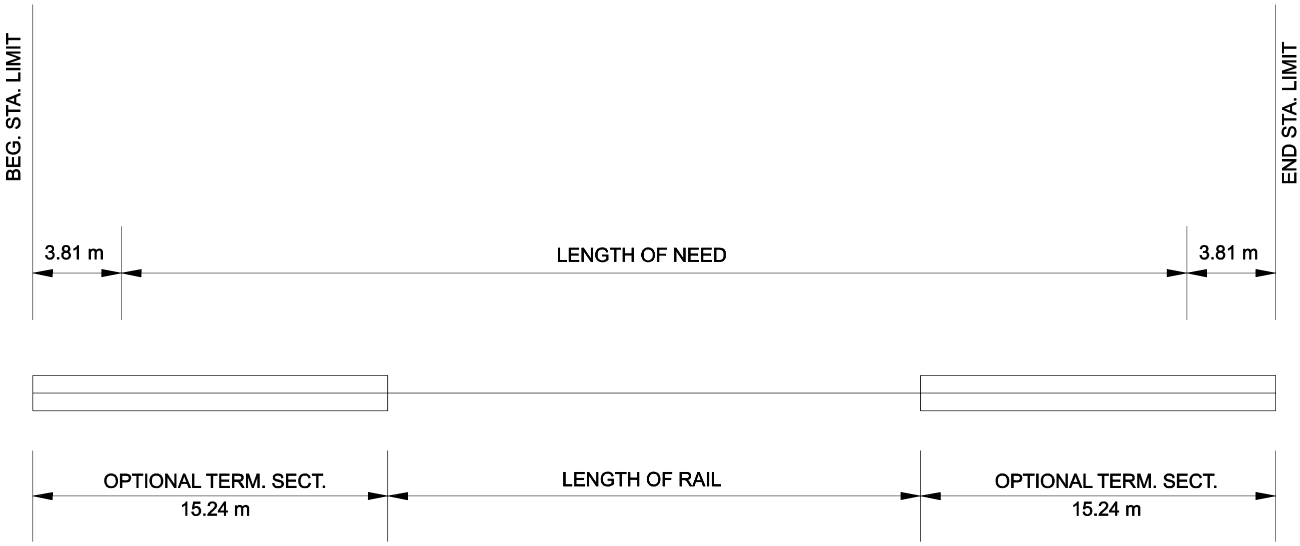
1. Compute length of need rounded to a multiple of 12.5’.
2. Add 12.5’ to each end of length of need to establish beginning and ending stations.
3. The difference between beginning and ending stations minus (2 x 50.0’) = length of rail.

Example: Guardrail is warranted between Stations 9 + 90 and 15 + 00

4. (15 + 00 - 9 + 90) ÷ 12.5 = 40.8 Rnd ⇒ 41
5. 41 x 12.5 = 512.5’ Length of Need
6. 9 + 90 - 12.5 = 9 + 77.5 Beginning Station
7. 9 + 77.5 + 512.5 + (2)(12.5) = 15 + 15.00 Ending Station
8. 15 + 15.00 - 9 + 77.5 - (2)(50) = 437.5’ Length of Rail

OPTIONAL TERMINAL SECTION

Figure 5.4L (US Customary)



Steps:

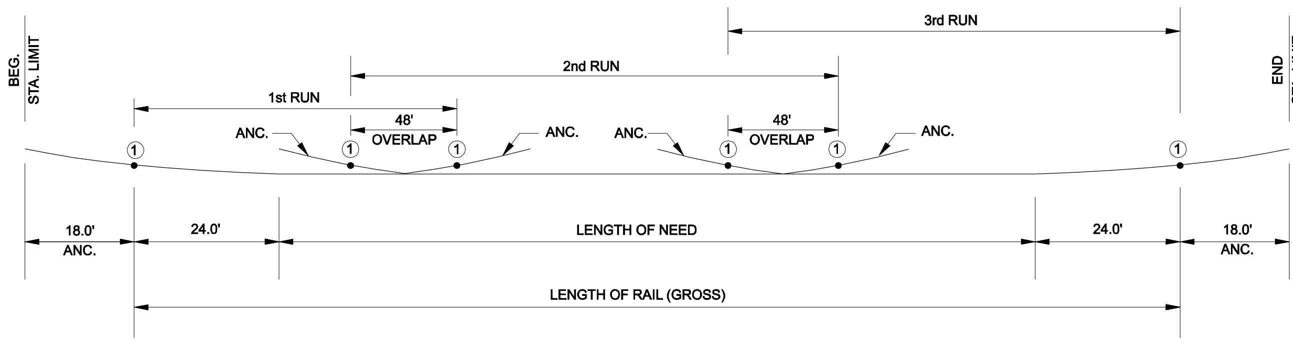
1. Compute length of need rounded to a multiple of 3.81 m.
2. Add 3.81 m to each end of length of need to establish beginning and ending stations.
3. The difference between beginning and ending stations minus (2 x 15.24 m) = length of rail.

Example: Guardrail is warranted between Stations 10 + 00 and 15 + 00

1. (15 + 00 - 10 + 00) ÷ 3.81 = 131.2 Rnd $\Rightarrow$ 132
2. 132 x 3.81 = 502.92 m Length of Need
3. 10 + 00 - 3.81 = 9 + 96.19 Beginning Station
4. 9 + 96.19 + 502.92 + (2 x 3.81) = 15 + 06.73 Ending Station
5. 15 + 06.73 - 9 + 96.19 - (2 x 15.24) = 480.06 m Length of Rail

OPTIONAL TERMINAL SECTION

Figure 5.4L (Metric)



Steps:

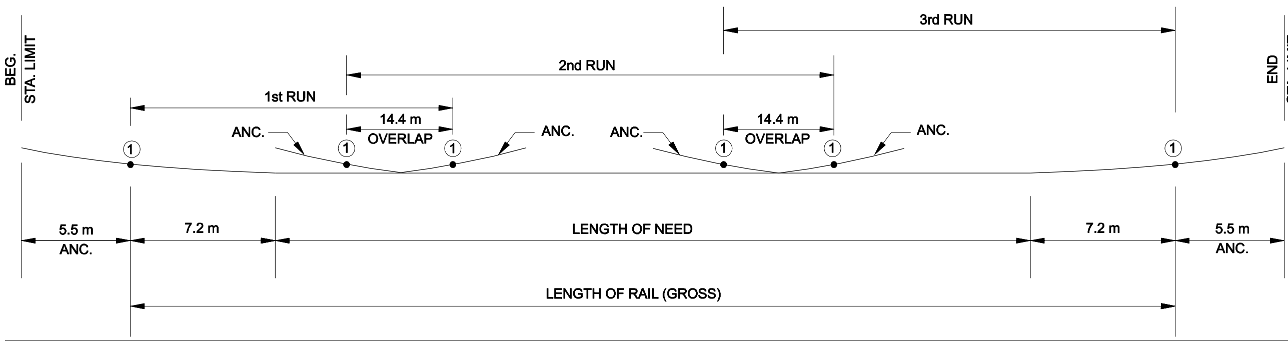
1. Compute length of need rounded to a multiple of 16'.
2. *Add 42' to each end of the needed rail length to establish the beginning and ending stations.*
3. *The difference between beginning and ending stations minus the length of anchor sections (2 x 18') = length of rail (gross).*
4. *Length of rail (gross) ÷ 2000' = number of runs (round up to nearest whole number).*
5. *(No. of runs - 1) x 48' added to length of rail (gross) = total payment length of cable rail.*
6. *No. of runs x 2 = number of anchors.*

Example: Guardrail is warranted between Sta 20 + 00 and 55 + 00.

1. (55 + 00 - 20 + 00) ÷ 16.0 = 218.75 Rnd ⇒ 219
   (219)(16) = 3504' Length of Need
2. 20 + 00 – 42 = 19 + 58.0 Beginning Station
   19 + 58.0 + 3504.0 + (2)(42) = 55 + 46.0 Ending Station
3. 55 + 46.0 - 19 + 58.0 - (2)(18) = 3552.0' (gross) Length of Rail
4. 3554 ÷ 2000 = 1.78 Rnd ⇒ 2 Runs
5. (2 - 1)(48) + 3552 = 3600.0 Length of Cable Rail for Payment
6. 2 x 2 = 4 Anchors

CABLE GUARDRAIL

Figure 5.4M (US Customary)



Steps:

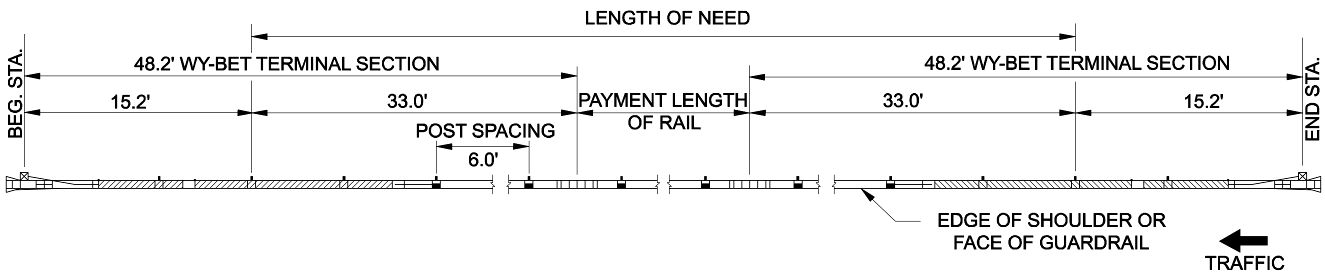
1. Compute length of need rounded to a multiple of 5.0 m.
2. *Add 12.7 m to each end of the needed rail length to establish the beginning and ending stations.*
3. *The difference between beginning and ending stations minus the length of anchor sections (2 x 5.5 m) = length of rail (gross).*
4. *Length of rail (gross) ÷ 609.4 m = number of runs (round up to nearest whole number).*
5. *(No. of runs - 1) x 14.4 m added to length of rail (gross) = total payment length of cable rail.*
6. *No. of runs x 2 = number of anchors.*

Example: Guardrail is warranted between Sta 20 + 00 and 35 + 00.

1. (35 + 00 - 20 + 00) ÷ 5.0 = 300.00 Rnd⇑ 300
   300 x 5.0 = 1500.0 m Length of Need
2. 20 + 00 - 12.7 = 19 + 87.3 Beginning Station
   19 + 87.3 + 1500.0 + (2 x 12.7) = 35 + 12.7 Ending Station
3. 35 + 12.7 - 19 + 87.3 - (2 x 5.5) = 1514.4 m (gross) Length of Rail
4. 1514.4 ÷ 609.4 = 2.48 Rnd⇑ 3 Runs
5. (3 - 1) x 14.4 + 1514.4 = 1543.20 m Length of Cable Rail for Payment
6. 3 x 2 = 6 Anchors

CABLE GUARDRAIL

Figure 5.4M (Metric)



Steps:

1. Compute the length of need, minus 33.0’ for each terminal section, rounded to a multiple of 18.0’ = payment length of box beam guardrail.
2. Add 48.2’ to each end of the rounded length of need to establish the beginning and ending stations.
3. The WY-BET Terminal Section (48.2’) is bid per each including the end anchor (no separate payment is made for the end anchor).

Example: Guardrail is warranted between Stations 17+50 and 32+75.

1. [(32+75 - 17+50) - (2)(33)] ÷ 18 = 81.06 Round $\Rightarrow$ 82

   (82)(18) = 1476’ Payment Length of Box Beam Guardrail

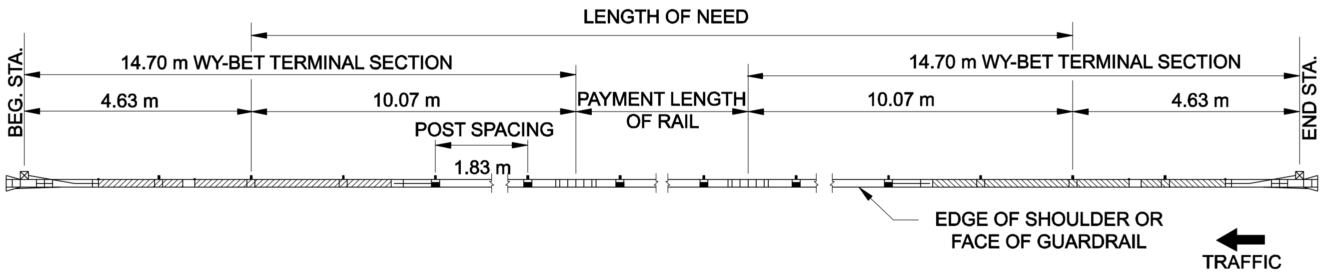
2. (17+50 + 33) – 48.2 = 17 + 34.80 Beginning Station

   1734.80 + 1476 + (2)(48.2) = 33 + 07.20 Ending Station

3. 2 WY-BET Terminal Sections

BOX BEAM GUARDRAIL

Figure 5.4N (US Customary)



Steps:

4. Compute the length of need, minus 10.07 m for each terminal section, rounded to a multiple of 5.49 m = payment length of box beam guardrail.
5. Add 14.70 m to each end of the rounded length of need to establish the beginning and ending stations.
6. The WY-BET Terminal Section (14.70 m) is bid per each including the end anchor (no separate payment is made for the end anchor).

Example: Guardrail is warranted between Stations 17+50 and 22+75.

7. [(22+75 - 17+50) - (2 x 10.07)] ÷ 5.49 = 91.96 Round ⇑ 92

   92 x 5.49 = 505.08 m Payment Length of Box Beam Guardrail

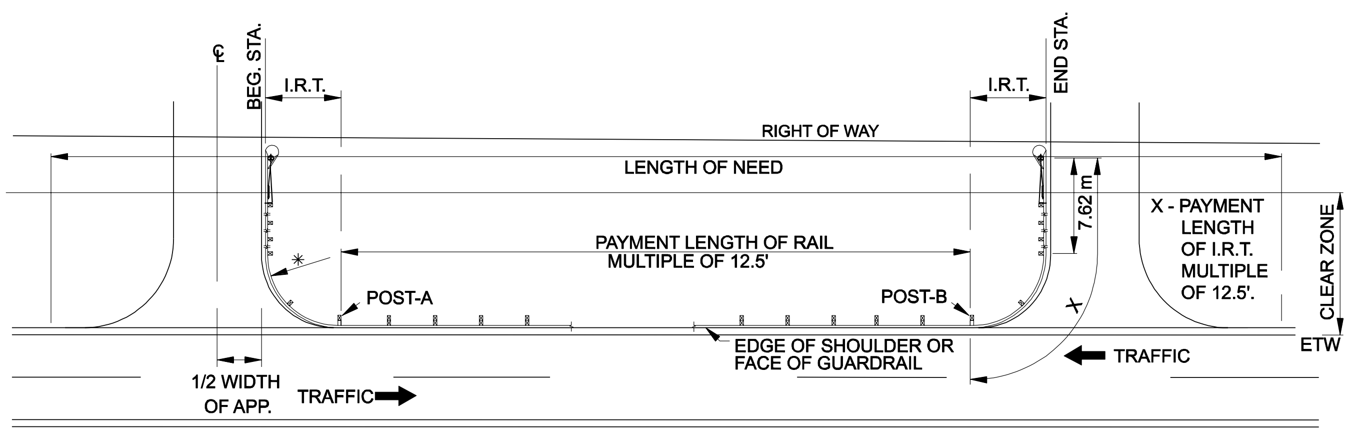
8. (17+50 + 10.07) - 14.70 = 17 + 45.37 Beginning Station

   17+45.37 + 505.08 + (2 x 14.70) = 22 + 79.85 Ending Station

9. 2 WY-BET Terminal Sections

BOX BEAM GUARDRAIL

Figure 5.4N (Metric)



*Note: The radius for any particular installation is constant. Select a radius that best fits approach radius from table.

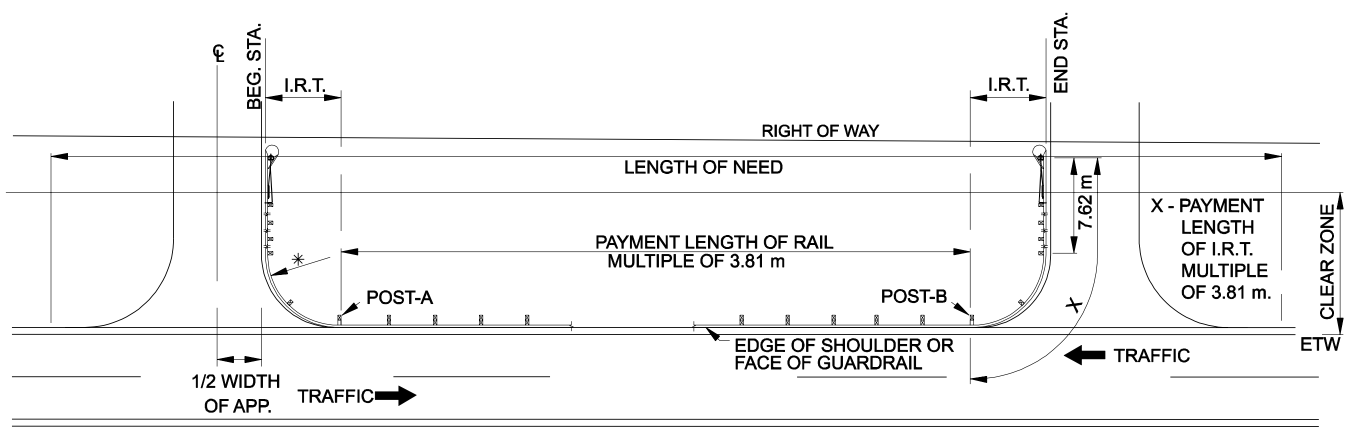
Radius	Length of Bent Rail	Total Length of I.R.T.
8’	12.5’	37.5’
16’	25’	50’
24’	37.5’	62.5’
32’	50.0’	75.0’

Note: Dynamic deflection distance for rail is 4‘.

1. Determine barrier warrants (Section 14.3).
2. Calculate advancement and departure lengths. (Section 14.4.3).
3. If approaches, turnouts or other obstacles are within the required length of guardrail, I.R.T. terminals may be used to shorten the required lengths.
4. Ensure that R/W width is sufficient (i.e., far enough from the shoulder to get the full I.R.T. installed without encroaching).
5. Determine the edge of each approach.
6. Determine the location of Post-A and Post-B.
7. Determine the best fit radius from the table, based on the difference between the edge of approach and Post-A. Repeat for Post-B.
8. Minor adjustments to the approach stationing or minor grading along the edge of the approach may be necessary to fit the I.R.T. to the approach.
9. Station of Post-A minus the radius = the beginning station of rail. Station of Post-B plus the radius = the end station of guardrail.
10. The distance between Post-A and Post-B is the payment length of guardrail.
11. The payment length for the I.R.T. is the length of bent rail plus 25’.
12. I.R.T. end anchors are not bid separately.

COMPUTATIONS OF PAY QUANTITIES FOR W-BEAM GUARDRAIL AND INTERSECTING ROADWAY TERMINAL (IRT) SECTIONS

Figure 5.4O (US Customary)



*Note: The radius for any particular installation is constant. Select a radius that best fits approach radius from table.

Radius	Length of Bent Rail	Total Length of I.R.T.
2.45 m	3.81 m	11.43 m
4.85 m	7.62 m	15.24 m
7.30 m	11.43 m	19.05 m
9.70 m	15.24 m	22.86 m

Note: Dynamic deflection distance for rail is 1.2 m.

1. Determine barrier warrants (Section 14.3).
2. Calculate advancement and departure lengths. (Section 14.4.3).
3. If approaches, turnouts or other obstacles are within the required length of guardrail, I.R.T. terminals may be used to shorten the required lengths.
4. Ensure that R/W width is sufficient (i.e., far enough from the shoulder to get the full I.R.T. installed without encroaching).
5. Determine the edge of each approach.
6. Determine the location of Post-A and Post-B.
7. Determine the best fit radius from the table, based on the difference between the edge of approach and Post-A. Repeat for Post-B.
8. Minor adjustments to the approach stationing or minor grading along the edge of the approach may be necessary to fit the I.R.T. to the approach.
9. Station of Post-A minus the radius = the beginning station of rail. Station of Post-B plus the radius = the end station of guardrail.
10. The distance between Post-A and Post-B is the payment length of guardrail.
11. The payment length for the I.R.T. is the length of bent rail plus 1.62 m.
12. I.R.T. end anchors are not bid separately.

COMPUTATIONS OF PAY QUANTITIES FOR W-BEAM GUARDRAIL AND INTERSECTING ROADWAY TERMINAL (IRT) SECTIONS

Figure 5.4O (Metric)

12. Impact Attenuators. Using the manufacturer's guidelines, determine the number of bays required based on the design speed at the site. Impact attenuators are included in the station limits of the guardrail but are a separate bid item. Attenuators are bid as a unit (i.e., each).

13. Stiffened Guardrail Sections. Compute the length of stiffened guardrail and round up to the next highest multiple of 12.5' (3.81 m). Include the length of transitions (bridge approach sections) in the length computed for stiffened guardrail. See MDT Detailed Drawings for configuration on one-way and two-way roadways.

5.4.4.3 Curb and Gutter

Section 11.2.6 provides the Department criteria for curb and gutter sections. Show the curb and gutter station limits in the Curb Frame from the beginning of one curb return to the beginning of the next curb return (BCR to BCR). Figure 13.2B illustrates the location of the BCR. In addition to the length of the curb and gutter between BCR's, the distance of the curb and gutter around the radius to the end of the curb return must also be included in the summary quantities. Radii dimensions are to the back of curb. Round the curb and gutter quantities in the Curb Frame to the nearest 0.1' (0.1 m).

5.4.4.4 Sidewalks

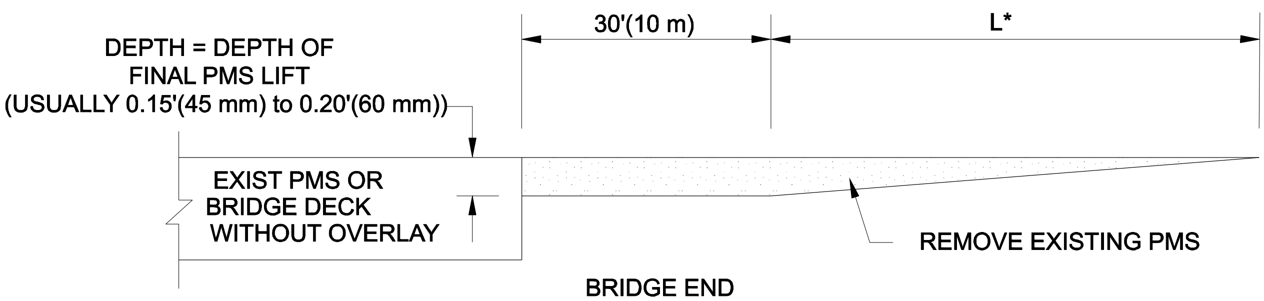
Section 11.2.7 provides the Department criteria for sidewalks. For each depth of sidewalk in the project, compute the sidewalk area in square yards (meters) and round to the nearest 0.1 square yard (0.1 square meter). Report the results in the Sidewalk Frame. The cost for the aggregate base is typically incorporated in the unit cost per square yard (meter) of sidewalk. For sidewalk sections under vehicular traffic (e.g., intersections with approaches and alleys), use a 6" (150 mm) sidewalk depth. For all other locations, use a 4" (100 mm) sidewalk depth. Curb ramps are included in the 4" (100 mm) sidewalk quantities and are not a separate bid item. The curbing around the curb ramp is paid for as curb and gutter and is typically included in the curb radii of curb and gutter; see Section 5.4.4.3.

5.4.4.5 Truncated Domes

See Chapter 16

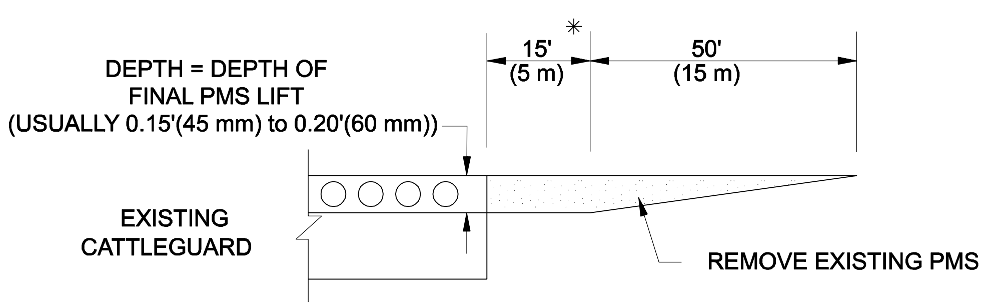
5.4.4.6 Cold Milling

Cold milling is used to remove a specified depth of pavement. Where the pavement has deteriorated, the removal of all pavement above the plane of failure may be necessary prior to placing a new overlay. For these cases, the depth of milling will be determined by the Surfacing Design Section. Cold milling is also used in conjunction with overlays to match the new surfacing elevations at bridge decks, cattle guards and connections to existing pavement; see Figure 5.4P.



** L is calculated based on 30'(10 m) of taper per 0.05'(15 mm) of plant mix thickness. L only will be used for connection to PTW.*

Example: For a 0.20' (60 mm) overlay $L=\left(\frac{0.20}{0.05}\right)(30)=120'$ $\left(L=\left(\frac{60}{15}\right)(10)=40m\right)$



* *Add the following note to the Detail Sheet in the contract plans: "Actual removal distances to be determined during construction by the Engineer."*

COLD MILLING TAPERS

Figure 5.4P

Typically, wherever milling is required, remove all plant-mix material from concrete bridge decks within the project limits. Otherwise, written documentation is required. See Figure 5.4P to determine the extent of milling beyond the bridge ends;. For cattle guards, the pavement is typically milled for 65' (20 m) on either side of the structure. Review the application of this criteria during the Plan-In-Hand Field Review. Standard milling widths are 6.25', 12.5' and 14.0' (1.905 m, 3.810 m and 4.267 m). Avoid using costly non-standard milling widths unless absolutely necessary. Use the bottom width of the milled surface to compute the cold milling area and round to the nearest square meter. Where milling depth tapers used maximum width (i.e. width at the bottom of the milled surface) to calculate the cold milling area. Record the results in the Cold Milling Frame.

5.4.4.7 Pavement Pulverization

Pavement pulverization is used to produce a uniform material for the total subgrade width by mixing the existing bituminous pavement with aggregate. Specify the depth of pavement pulverization based on Surfacing Design recommendation. The depth of the pulverization is the average depth of the existing bituminous pavement. Use the bottom width of the pulverized surface base on the specified depth to compute the quantity of pavement pulverization. Calculate the area in square yards (meters) and round to the nearest square yard (meter). Record the results in the Surfacing Frame.

Aggregate added to the pulverized material for leveling is measured by the ton (metric ton). Calculate the quantity and round the results as shown in Section 5.4.2.2. Record the results in the Pulverization Frame. Provide a design profile grade where pavement pulverization is specified. The Design profile grade should be adjusted as necessary to account for leveling and swell of pulverized material.

5.4.4.8 Finish Grade Control

Record finish grade control staking quantities in the finish grade control Staking Frame on the Summary Sheets. Also consider the following:

1. Each course mile (kilometer) of finish grade control staking is based on a 2-lane roadway, including shoulders and ditches.
2. Each traffic lane, ramp, climbing lane, etc., is one-half of a course mile (kilometer) for measurement. Do not measure parking lanes, turning lanes, median lanes and chaining areas separately from the adjacent roadway.
3. Four-lane facilities require separate measurements for each roadway.
4. Measure the subgrade and each base course of aggregate requiring finish grade control staking separately, by the course mile (kilometer), for each roadway, ramp, intersecting roadway, PTW connections, temporary detour and frontage road.
5. For facilities with aggregate surfaces, finish grade control is only provided for the subgrade if the aggregate is paid for by the (metric) ton. However, finish grade control is provided for both subgrade and aggregate surfacing if the aggregate is paid for by the cubic yard (meter). A separate course of finish grade control staking will be required where special borrow is used.
6. Take measurements along the centerline of each roadway and round to the nearest 0.1 mile (0.1 km).

The following example illustrates how to calculate finish grade control staking for a project.

* * * * * * * * * *

<u>Example 5.4-4</u>

Given: 4-lane freeway with 7 miles (km) of construction
Interchange with construction of four 0.4 mile (km) long ramps
2-lane intersecting roadway with 1 mile (km) of construction

Pavement section:

0.25’ (75 mm) Plant Mix
1.00’ (300 mm) Crushed Aggregate Course
1.25’ (375 mm) Selected Surfacing

Problem: Determine the amount of finish grade control staking required for the project.

Solution: Calculate the course mile (kilometer) of finish grade control staking for the mainline, ramps and intersecting roadway:

14.0	mile (km) subgrade — mainline
14.0	mile (km) selected surfacing — mainline
14.0	mile (km) crushed aggregate — mainline
0.8	mile (km) subgrade — ramps
0.8	mile (km) selected surfacing — ramps
0.8	mile (km) crushed aggregate — ramps
1.0	mile (km) subgrade — intersecting road
1.0	mile (km) selected surfacing — intersecting road
1.0	mile (km) crushed aggregate — intersecting road
47.4	mile (km) total

* * * * * * * * * *

5.4.4.9 Traffic Gravel

Traffic gravel is used as temporary surfacing to carry traffic on stages of unfinished grading (i.e., cuts or fills). For the areas where the traffic cannot be maintained on the PTW or finished subgrade, determine the number of stages the cut or fill will be constructed. Compute the quantity of traffic gravel based on the following criteria:

1. 24-foot (7.2 m) minimum travel width,
2. 0.20’ (65 mm) depth of traffic gravel,
3. the length of temporary surfacing.

When specifying traffic gravel, use the type and grade of crushed aggregate course specified for the project. Verify traffic gravel quantities with district construction personnel. Traffic gravel is measured and paid by the (metric) tons. Round the calculated quantity to the nearest (metric) ton and record the quantity in the “TRAFFIC GRAVEL” column of the Surfacing Frame.

5.4.4.10 Rumble Strips

See Section 11.2.2.6 for criteria for rumble strips. When calculating rumble strip quantities, consider the following guidelines:

1. Each individual line of rumble strip is measured separately for payment.

2. Deduct gaps for bridges, ramps, approaches, etc., from the length quantity for rumble strips.

3. Discontinue rumble strips on shoulders less than 6’ (1.8 m) wide if guardrail exists or is proposed.

4. Take measurements along the centerline of the roadway and round to the nearest 0.1 miles (0.1 km).

5. Record the rounded quantity in the Rumble Strips Frame.

6. Fog Seal When fog seal is specified for rumble strips use SS-1 applied to a width of 2’ (0.6 m) at an application rate of 0.05 gal/sq yd (0.2 L/m^2)

5.5 MISCELLANEOUS COMPUTATIONS

5.5.1 Lump-Sum Items

Use lump-sum bid items where the scope of work for the item is clearly defined and the amount of work has a minimal chance of changing during construction. Lump-sum should also considered where the end result is defined but there are various methods of achieving the desired results. Including an item of work in another item should only be done where the scope of work for each item is clearly defined and the chance of the quantity of either item changing is minimal. Where practical, list separately the quantities that comprise the lump-sum item of work. The list should note that the separate "quantities are for estimating purposes only." Provide a clear definition of work for each item whether it is bid by the unit, included in the cost of other items or bid lump sum. Where there is a significant chance of quantity change, the work must be bid by the unit. Where lump-sum items are used, the total quantity for the project should always equal one. If more than one item or location is included in the lump-sum show the decimal proportion of the work of each location. For example, a project which includes the removal of three structures being 30’, 30’, 60’ (10, 10, 20 meters) long the proportion would be .25, .25, .50 respectively.

5.5.2 Clearing and Grubbing

Clearing and grubbing is typically included in the construction plans and, generally, will not require a separate set of plans. Decisions related to the payment method (e.g., lump sum, absorbed in other bid items, by the acres or hectare) should be made during the Plan-in-Hand Field Review. Payments based on the number of acres (hectares) involved require the quantities to be presented on the Clearing and Grubbing Frame. Where clearing and grubbing will be included in the grading bid item -, include an appropriate note in the Notes Sheet. Clearing and grubbing may be bid either as separate bid items with different bases for payment or as a single item. If the clearing and grubbing has separate phases, the quantities for each should be shown separately in the summary and the special provisions should describe the measurement and payment for each phase. The decision on the disposition and areas of selective cutting will be made at the Plan-in-Hand Field Review. The disposition of merchantable timber should be determined during right-of-way negotiations.

5.5.3 Topsoil

In general, topsoil will be required on most projects. The designer should review the following relative to the placement of topsoil:

1. Topsoiled Areas. Provide topsoil according to the following guidelines:

a. Topsoil will be required on all projects where the existing topsoil is disturbed. Where topsoil is impractical to salvage or is unsuitable (i.e. rock cut), eliminate the area from the topsoil salvage quantity. Also provide a special provision describing the special slope treatment to be used.

b. Provide topsoil on all 2:1 or flatter slopes.

c. Place topsoil on the gravel surfacing inslope to the edge of the plant mix for all projects that involve disturbance of the inslope as per the *MDT Detail Drawings*.

2. Topsoil. Assume that the existing topsoil will be salvaged and stockpiled unless otherwise noted.

3. Placement. Where required, provide topsoil to a loose depth of 4"(100 mm) from the subgrade shoulder to the catch point. Slopes other than serrated slopes should be scarified and conditioned to leave a rough surface suitable to catch and hold topsoil.

4. Quantities. Use the following procedure to compute topsoil quantities and record them on the summary sheets:

   a. Topsoil quantities should be based on a 4"(100 mm) depth unless otherwise determined by topsoil survey.

   b. Show topsoil quantities, in cubic yards (meters), in 3000' (1000 m) increments in the Topsoil and Seeding Frame.

   c. Topsoil quantities can be obtained using computer-generated data or manually calculated computation sheets.

5. Topsoil Replacement. Use the following procedure to treat topsoil replacement regardless of the quantity of topsoil on a project:

   a. Topsoil replacement = (topsoil) x (1 + project shrink factor).

   b. Include the topsoil replacement quantities in the mass diagram using 3000 ft (1000 m) increments.

   c. Include the total topsoil replacement quantity line item in the Additional Grading Frame as "EMB +" in the "included in roadway quantities" column.

5.5.4 Seeding

Where seeding is provided on a project, consider the following guidelines:

1. Seeded Areas. Provide seeding on all slopes extending from the edge of plant mix to the new right-of-way limit, except on slopes steeper than 1.5:1, areas that are predominantly rock and other locations that are difficult to grow grass.

2. Determining Quantities. The Environmental Services Bureau is responsible for determining the seed type, seeding rate, amount of fertilizer and mulch used per acre (hectare). Generally, different seeding rates will be specified for:

   a. the total area to be seeded inside the new right-of-way having 3:1 or flatter slopes (Area 1) minus the areas described below,

   b. constructed slopes steeper than 3:1 (Area 2),

   c. a strip extending from a point from the edge of the plant mix to a distance of 15’ (4.5 m) or to the edge of the surfacing inslope, whichever is greater (Area 3), and

   d. other specified areas.

   The designer will be responsible for determining the size of the area to be seeded at each rate using computer generated data or manually calculated computation sheets. The number of acres (hectares) in Area 1 that require seeding are calculated as follows:

   Area 1 = R/W - Area 2 - Area 3 - Surface Area

   Where:

   R/W = The total area inside the new right-of-way
   Surface Area = (Finished top width) x (length of project)

   No fertilizer is required for Area 3.

3. Recording Quantities. Record the seeding areas in the Topsoil and Seeding Frame. The seeding areas should be recorded as follows:

   a. Present the number of separate acres (hectares) for areas on slopes of 3:1 or flatter, areas on slopes steeper than 3:1, the 15’ (4.5 m) wide strip adjacent to the edge of pavement and for other areas defined in the seeding recommendations.

b. For Area 1 and Area 3 seeding conditions, provide areas of seed bed conditioning in hectares. Mulch, in acres (hectares), is generally provided for Area 2 conditions.

5.5.5 Fencing

Section 18.3 and the MDT Detailed Drawings present the Department criteria for the design and placement of fencing. For quantity estimating, consider the following guidelines:

1. Fence Types. Section 18.3 presents the most common fencing types used by the Department. Refer to the right-of-way agreements to determine the type of fence required. Fencing is typically measured to the nearest foot (0.1 meter). The length of fence does not include cattle guard, gates or other openings. These items are paid for separately.

2. Temporary Fencing. The length around the construction permit areas should be used to determine the quantity of temporary fence.

3. Panels. See Figure 18.3A to determine the type and number of fence panels that should be used with a run of fencing.

4. Deadman. For estimating purposes, include the following number of deadmen per kilometer of fence based on the type of terrain:

    a. flat terrain — 2 deadman per mile (1 per kilometer) of fence
    b. rolling terrain — 5 deadmen per mile (3 per kilometer) of fence
    c. rough terrain — 8 deadmen per mile (5 per kilometer) of fence

5. Gates. Most gates used by the Department should be measured in 2’ (0.6 m) increments.

6. Recording. Include all fencing quantities in the Fencing Frame. List the fence lengths for the left side of the roadway from the beginning station to ending station, and then for the right side from beginning to ending station. Terminate the stationing at each parcel (R/W Agreement), change in fence or post type, gates, cattle guards, or other openings. In general, the length of fence can be determined by subtracting stationing. Lateral fences, winged fences and sharp R/W breaks should be scaled to determine fence lengths. Also include the following information in the fencing summary:

    a. The "FENCE TYPE" column heading should include the post designation (e.g., F4M, F4W) where:

M = metal posts
W = wood posts

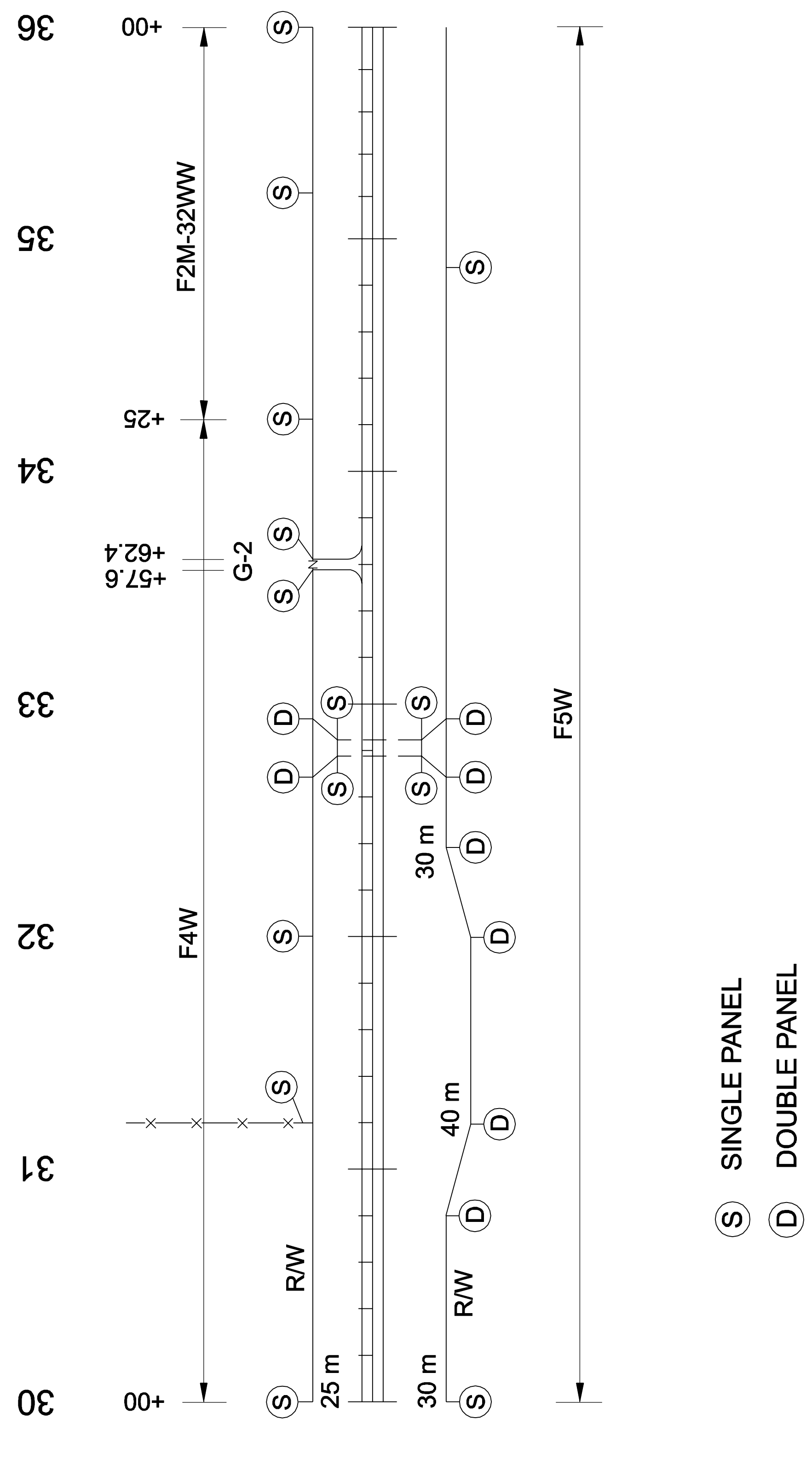
b. Call out the gates by station at each end of the gate and list them according to type.

c. Show totals only for temporary fence and deadmen.

7. Fencing Plans. If requested by the District, prepare fencing plans on a set of full size, white prints of the R/W plans. Figure 5.5B shows how the fencing plans should be prepared. Do not include the fencing plans in the contract package, but transmit them to the District at the time of the project letting.

5.5.6 Cattle Guards

Section 18.9 and the MDT Detailed Drawings present the Department criteria for the design and placement of cattle guards. For quantity measurements, note that cattle guards are available in two standard sizes: 10’ x 8’ (3.05 m x 2.44 m) and 12’ x 8’ (3.66 m x 2.44 m). For most roadways, two 12’ x 8’ (3.66 m x 2.44 m) cattle guards will provide an adequate design. In all cases, extend the cattle guard fully across the finished surface width, including finished shoulders. Itemize the number of cattle guards in the Cattle Guard Frame.



SAMPLE FENCING PLAN

Figure 5.5B

5.5.7 Concrete Slope Protection

Design concrete slope protection, used for bridge end slopes, as shown in the *MDT Detailed Drawings*. Estimate quantities of concrete slope protection in square yards (square meters) of concrete rounded to the nearest 0.1 sq yd (0.1 m^2).

5.5.8 Detours

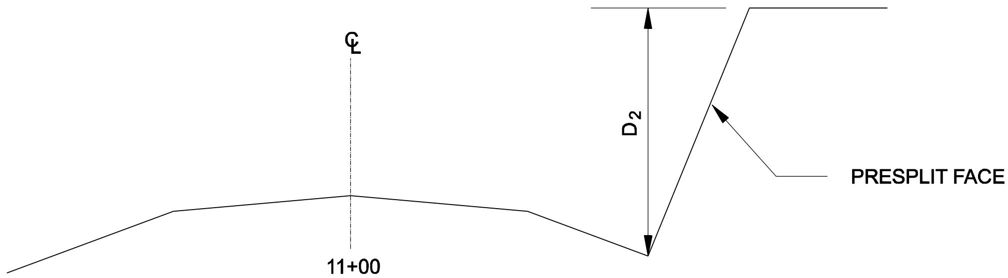
During the construction of a project, a detour often is constructed, maintained and removed. Provide sufficient details for all detours on a project. The details include the plan and profile of the detour, the typical section of the detour, the design speed of the detour and a list of the components and quantities necessary to construct the detour. The quantities are for informational purposes only. The construction, maintenance and removal of the detour will be paid for as a lump-sum bid item. Section 4.4 provides an example of a detour detail. Include the detour typical section with the project typical sections.

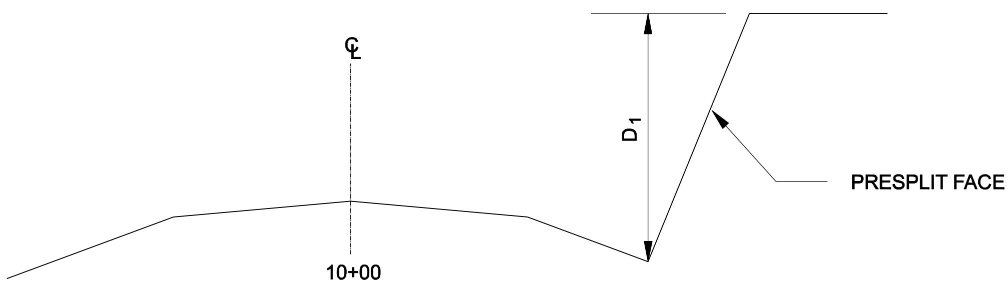
Waterway openings for detours will consist of recommendations from the Hydraulics Section for a specific drainage structure (e.g., pipes, bridge), or a statement in the special provisions that the contractor will provide an adequate waterway opening for the detour. Include the cost of any required drainage structures in the lump-sum bid for "Construct, Maintain and Remove Detour."

5.5.9 Pre-Splitting Rock Slopes

Pre-splitting rock cuts is used to produce a continuous or semi-continuous fracture between drill holes and a stable rock cut, and to eliminate overbreak in the backslope during primary blasting. Pre-splitting rock cut to a smooth plane is achieved by detonating evenly spaced holes prior to detonation of the production holes. Pre-splitting rock cuts will be recommended by the Geotechnical Section, if needed.

Drill pre-splitting holes are measured by the foot (meter) for each hole. The measurement is made from the rock surface to the roadway grade or to a predetermined bench elevation; see Figure 5.5C. A 30” (765 mm) interval is used to estimate the number of drilling pre-splitting holes. Record the computed length of holes in the Drill Pre-Splitting Holes Frame.





Calculate presplitting as follows:

$\frac{D_1 + D_2 + \ldots}{N} xL = m^2$ Area of rock face (US Customary use the same equation and the answer is in square feet)

$\frac{m^2}{0.765}$ =Total length of presplitting holes US Customary equation is $ft^2/2.5$ = length

Where:

$D_1, D_2, ect. \rightarrow$	=	depth of presplit on each cross section
N	=	number of cross sections
L	=	horizontal length of presplit area

PRESPLITTING ROCK SLOPES

Figure 5.5C